TWENTY-SEVENTH ANNUAL REPORT

OF THE

New York State College of Agriculture

AT

CORNELL UNIVERSITY

AND THE

Agricultural Experiment Station

Established under the direction of Cornell University

ITHACA, NEW YORK

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OF THE

New York State College of Agriculture at Cornell University and the Agricultural Experiment Station Established under the Direction of Cornell University

STATE OF NEW YORK

Department of Agriculture

Albany, *January* 15, 1915

To the Honorable the Legislature of the State of New York:

In accordance with the provisions of the statutes relating thereto, I have the honor to transmit herewith the Twenty-seventh Annual Report of the New York State College of Agriculture at Cornell University, as a part of the Twenty-second Annual Report of the Commissioner of Agriculture.

CALVIN J. HUSON,
Commissioner of Agriculture.

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The regular bulletins of the Station are sent free on request to residents of New York State.

November 23, 1914

The Governor of the State of New York,
Albany, New York.

The Secretary of the Treasury,
Washington, D. C.

The Secretary of Agriculture,
Washington, D. C.

The Commissioner of Agriculture,
Albany, New York.

In conformity with the law and practices of former years, I beg to submit on behalf of Cornell University the accompanying report of the New York State College of Agriculture for the year 1913–1914, signed by the Director of the College.

This report, together with the abstracts of the work of the different departments, and copies of the various publications of the year, set forth in such detail the activities of the College that it is unnecessary to dwell at length upon any particular feature of the work.

During the year the work of the College was in charge of William Alonzo Stocking, jr., Professor of Dairy Industry, as Acting Director. On August 1, 1914, Dr. Beverly T. Galloway, formerly Chief of the Bureau of Plant Industry of the United States Department of Agriculture, but more recently Assistant Secretary of Agriculture, was appointed Dean and Director of the College. Dr. Galloway's report is a summary of the activities of the institution under Acting Director Stocking, and, as announced by him, it is yet too early to make any definite statements regarding a number of plans looking toward further advancement of the College.

In closing, it is proper that I should express my commendation of the service rendered the College by Professor Stocking. His work was loyally and faithfully performed, and the institution progressed satisfactorily under his management. Professor Stocking has resumed his position as head of the Department of Dairy Industry.

Respectfully submitted,
JACOB GOULD SCHURMAN,
President of Cornell University.

REPORT OF THE DIRECTOR OF THE NEW YORK STATE COLLEGE OF AGRICULTURE

November 23, 1914

To the President of the University:

SIR:—I have the honor to submit herewith the report of the New York State College of Agriculture for the academic year 1913–1914.

In your report of last year, you recorded the resignation of Dr. L. H. Bailey as Director of the New York State College of Agriculture and the appointment of W. A. Stocking, jr., as Acting Director for the year 1913–1914, the appointment to take effect on August 1. The present report, therefore, represents the progress of the College of Agriculture and the Agricultural Experiment Station under the direction of Acting Director Stocking.

Professor Stocking brought to the administration of the College accuracy and maturity of thought and judgment, keen executive sense growing out of his experience as head of the Department of Dairy Industry with its large commercial development, high educational ideals, and an integrity which made his administration a marked success and which won for him an increased respect and esteem from his colleagues. The position of acting head, always a difficult one to fill, was discharged by Professor Stocking with singular ability, and with much satisfaction to the members of the staff. I desire to record my personal commendation of his administration. Professor Stocking has now resumed the headship of his department.

The writer was appointed Director of the College of Agriculture by the Board of Trustees of Cornell University at its meeting in June, and he took up his duties on August 1, 1914.

The year 1913–1914 was marked by the passing of the old Department of Horticulture and the organization of a separate Department of Floriculture under the direction of Professor E. A. White and a Department of Vegetable Gardening under Mr. Paul Work, the Department of Pomology having been previously established; the organization of a Department of Botany, into which was merged the former Department of Plant Physiology, with Professor K. M. Wiegand in charge; the active organization of a Department of Rural Education, with Professor George A. Works at the head; the coming of Professor R. A. Emerson as head of the Department of Plant Breeding to fill the place left vacant by the resignation of Professor Webber in 1913; the appointment of Professor M. C. Burritt as State Director of Farm Bureaus to succeed Professor L. S. Tenny, resigned; the

resignation of Professor Walter Mulford to accept the chair of forestry at the University of California, and the appointment of Professor R. S. Hosmer to the headship of the Department of Forestry; the retirement of Professor John Henry Comstock after more than forty years of distinguished and loyal service to Cornell University in the field of entomology; the launching of a new third, or summer, term of instruction, putting the College on the basis of twelve months teaching. Prior to the academic year covered by this report, provision had been made for the organization of the Departments of Floriculture, Vegetable Gardening, and Botany, but the active organization of these departments began on October 1, 1913.

EDUCATIONAL POLICY

The rapid increase in the number of students in the College of Agriculture during the last few years has made it difficult for the teaching staff to provide adequate facilities for the instruction of the student body. Agriculture is one of the newer fields of knowledge, and some time will yet be required to place our body of knowledge in good pedagogical form. During the present year the increase in the number of students has continued, but nevertheless the Faculty has been able to devote much careful study to the organization of its courses of instruction and the standardization of its work. For many years to come the work of the College will necessarily undergo gradual modification and improvement, and the lines of work that have been established during the rapid expansion of the College will be more definitely defined and settled. In a new field of collegiate education in which much pioneer work must be done, time and patience are required for the standardization of the instruction.

Under the law establishing the College of Agriculture as a state institution, the College is required to devote part of its energies to extension work away from the College. Formerly much of the extension work was done by members of the teaching staff. Believing that the highest standards of instruction will be best maintained when the instructing staff applies its energies mainly to the business of teaching without interruption, the Faculty has now fully indorsed the administrative policy adopted a few years ago, and already in good measure worked out, of having a special corps of persons for extension work so that it will be unnecessary for a member of the teaching staff to do nonresident extension work during the term in which he gives instruction to college classes; and the persons who are engaged in extension work will not, in general, be called upon for any duties other than those pertaining to the extension service.

Much consideration has been given in the last three or four years to the residence requirements for graduation. It has been possible for meritorious students to complete the requirements for graduation in seven terms,

and such graduation has been allowed. The Faculty feels, however, that time as well as subject matter is an important element in education and that eight terms of undergraduate work are essential, and it has adopted the policy of rigidly requiring eight terms of residence for graduation except in cases of students who, having completed their work in seven terms, wish to register in the graduate school. Such registration may be allowed only with the approval of two members of the candidate's graduate committee and the filing with the Secretary of the College of Agriculture of an acceptable schedule of work for the term. In such case the student shall not receive his bachelor's degree until the satisfactory completion of the eighth term of work has been reported by the Dean of the Graduate School to the Secretary of the College.

In the last report of the Director there was noted the establishment of a third term in the College of Agriculture, to be equal in length to each of the present terms. This third term has now been established and will extend this year from June 8 (immediately following the close of instruction in the second term) until September 23 (closing just before the beginning of instruction in the fall term). This gives a term substantially equivalent in length to each of the present university semesters. The offering of courses in this third term is optional with departments. It is not expected that all departments will offer work during this term. The departments most vitally interested in summer work are those having to do with the plant industries — including botany, plant breeding, plant pathology, pomology, soil technology, floriculture, and vegetable gardening — and with entomology, biology, and poultry husbandry. It is expected that the major part of the work given during the summer term will be offered by this group of departments. The summer term is established primarily for advanced and postgraduate study, and applicants are not eligible for admission until they have fully satisfied the fundamental work required in the freshman and sophomore years of our regular four-years course. In view of the fact that the introduction of a new term affects the organization of the entire college year, it has been possible this summer to offer only a limited number of courses. After the present year, when the readjustments will have been made, it is expected that courses will be given by other departments in addition to those mentioned above. A sufficient number of courses are offered for the present summer, however, so that students have considerable choice in arranging their schedules. The policy has been established that all required courses and those which are prerequisite to the fundamental work in other departments shall be given in either the fall or the spring term, or both, even though they may be repeated in the summer term. This provision will guard against any obligatory attendance in the summer term on the part of undergraduates.

ENTRANCE AGRICULTURE

In the year 1910 instruction in agriculture was introduced into the high schools of New York State as a regular four-years course under the supervision of the State Education Department. This instruction is now well organized in a considerable number of high schools, and applicants who have completed the four-years high school course in agriculture are now applying for admission to the State College of Agriculture. The College has followed the development of the high school instruction in agriculture carefully, anticipating the time when it would be desirable for the College to fully recognize the agriculture for admission. On May 6, 1914, the Faculty of Agriculture transmitted the following recommendation to the University Faculty:

> The Faculty of Agriculture recommends to the University Faculty that entrance subject No. 16, which now reads "Agriculture, ½ or 1 unit," be altered to read "No. 16. Agricultural subjects, ½ to 4 units"; and that a footnote be added that not to exceed four units will be allowed in vocational subjects.

This recommendation was received and approved by the University Faculty on May 8, 1914. The term "Agriculture," as here used, includes home economics.

This action will fully meet the requirements of the high schools in which four-years courses in agriculture have been introduced. At the same time it is a logical educational step for the University to take. The Faculty of the College fully recognizes the danger in encouraging over-much high school preparation in vocational subjects for admission to a college course which of itself is strongly vocational, but it has safeguarded itself by the provision that not to exceed four units in all vocational subjects shall be allowed for admission. Under the entrance requirements that were in force prior to the action of the University Faculty on May 8, it was already possible for applicants to offer three units in vocational subjects for admission to the University.

STUDENT REGISTRATION

The registration of students in the College of Agriculture for the year 1913–1914, including the Summer School and the Winter Courses, is as follows:

Graduate students		151
Regular students:		
Seniors	209	
Juniors	300	
Sophomores	363	
Freshmen	456	
		1,328

Special students		135
Winter-Course students:		
Agriculture	277	
Dairy Industry	106	
Home Economics	56	
Fruit Growing	49	
Poultry Husbandry	44	
Flower Growing	13	
Vegetable Gardening	10	
		555
Summer School in Agriculture		388
Total		2,557

During the year degrees have been conferred as follows:

Baccalaureate	207
Master's	21
Doctor's	12
	240

Sixteen more degrees are yet to be conferred as of the date of September 23, making the total number 256 for the year 1913–1914.

The increase in student registration this year over last year is 222.

It is of interest to note that the percentage increase in enrollment of undergraduates for the year is 15.8, while the percentage increase in students paying tuition is 93.8. This would appear to indicate that the rapid growth in number of students in the College of Agriculture during the past few years has not been strongly affected by the fact that tuition is not required of residents of New York State.

THE SUMMER SCHOOLS

By the inauguration of the third, or summer, term, the College of Agriculture has finally realized a long-cherished desire to give instruction to students in residence throughout the twelve months of the year. The first full-length summer term in the New York State College of Agriculture, and, it is believed, the first full-length summer term to be offered by any college of agriculture in this country, opened on June 8, 1914, and closed on September 23, 1914.

Necessarily, the beginning this year was small both in number of courses offered and in enrollment. The introduction of the new term affects the

organization of the entire college year, and some time will be required for the complete readjustments. Nevertheless, forty-eight courses of instruction were offered and practically all the classes were carried. The smaller classes were welcomed by both students and staff, and the summer's work was carried with very general satisfaction on the part of both.

On July 6, 1914, the fourth Summer School in Agriculture was opened. This six-weeks school is intended to meet the needs of principals, teachers, and supervisors of schools, with opportunities also for college students and others. From the beginning, about fifty per cent of the registration each summer has been made up of persons directly engaged in school work. During the four years since it was established, the summer school has had a substantial growth, as indicated by the following figures: 1911, 128 students; 1912, 223 students; 1913, 333 students; 1914, 388 students. From every standpoint, the school of the past summer may be regarded as the most satisfactory and successful of the four.

Throughout the week of July 13 to 18, the teachers of agriculture in the high schools of New York State met in conference at the College under the direction of Professor L. S. Hawkins, of the State Education Department. With three or four exceptions, all the teachers of agriculture in the State were present. The conference had an enrollment of fifty-one, although agriculture will be taught in only about forty-five high schools during the coming year. The conference concerned itself with the latest advancements in various lines of agriculture, together with methods of presenting subject matter to classes and to farmers' gatherings. There was considerable discussion, also, of the courses of study. The addresses were given by members of the college staff.

The fourth session of the School for Leadership in Country Life was held June 23 to July 3, 1914. The sessions were held in the Forestry Building, and the persons in attendance were housed in tents in the grove east of the main college buildings and adjacent to the Forestry Building. Not only was this arrangement convenient, but it fostered social intercourse, which added greatly to the pleasure of those in attendance. As in the past three years, work in rural sociology, rural ethics, rural leadership, rural economics, rural health and recreation, the rural social survey, leadership for country girls, and extension work in agriculture, was offered. Sixty persons, representing the following occupations, were in attendance: college teachers and extension workers, farm bureau managers, school principals and teachers, farmers, farmers' institute workers, country merchants, supervisors of girls' clubs, clergymen, Young Men's Christian Association and Young Women's Christian Association secretaries, officers of church organizations writers, editors, housekeepers, and college students. These persons came from New York, New Jersey, Pennsylvania, Maryland,

Massachusetts, Connecticut, Virginia, West Virginia, Indiana, Illinois, Michigan, North Carolina, Washington, and South Africa. A most valuable feature of the school was an extensive and well-selected exhibit of the work of rural organizations and institutions. It was the best exhibit of its kind that we have seen.

It is a satisfaction to all concerned that the facilities of the College are thus used continuously throughout the period when classrooms and laboratories are usually closed; and it is an equal satisfaction to have the facilities of the College utilized during the summer by persons who are unable, by reason of other employment, to enter the regular-term courses.

TEN YEARS AS A STATE COLLEGE

It was on May 12, 1904, that Governor Odell approved an act appropriating $250,000 for the erection of buildings for a College of Agriculture at Cornell University and establishing the College as a state institution with Dr. L. H. Bailey as Director. The present year completes the first decade in the history of the College as a state institution. A brief statement of the development that has taken place during this period is of interest.

In 1904 the only class building devoted exclusively to the purposes of the College of Agriculture was the old Dairy Building, now comprising a part of the north wing of Goldwin Smith Hall. In addition to this, the College occupied quarters in the north end of Morrill Hall and at the old forcing houses. The buildings of the College of Agriculture at that time were valued at about $60,000. At the present time the value of the buildings belonging to the College is approximately $1,250,000. At the beginning of this decade twenty-five courses of instruction were offered in agriculture. There were six full professors, one assistant professor, and two instructors. During the year 1913-1914 there have been two hundred and twenty-four courses of instruction offered in the College, and the Faculty has consisted of forty-six full professors, twenty-six assistant professors, and fifty-seven instructors. In the first year of the decade the student enrollment was two hundred and ninety-six; this year it is twenty-five hundred and twenty-six. It is interesting to note the fact that at the beginning of this period approximately one half of the total student body were special students, while at the end of this period less than one tenth are specials. This enormous growth in student body, teaching staff, and material equipment, is abundant evidence of the remarkable leadership of Director Bailey.

The Faculty of the College of Agriculture has presented to the University a portrait of Director Bailey painted by Henry Salem Hubbell. This portrait has been accepted by the University and is hung in the foyer of Bailey Hall.

COLLEGE STAFF

During the year the following professors have been added to the staff of the College of Agriculture:

Professor Edward Albert White, B.S., formerly head of the Department of Floriculture and Landscape Art at the Massachusetts State College of Agriculture, was elected Professor of Floriculture and head of the department on July 26, 1913. He took up the duties of his new position at the beginning of the academic year.

Professor Maurice Chase Burritt, B.S. in Agr., Extension Professor and State Director of Farm Bureaus, began his work on January 1, 1914, taking the place of Lloyd S. Tenny, resigned. Professor Burritt is a graduate of this College of Agriculture, and for some time preceding his appointment had been editor of the Tribune Farmer.

Professor George Alan Works, B.Ph., M.S. in Agr., formerly Associate Professor of Agricultural Education at the University of Minnesota, was appointed Professor of Rural Education on May 2, 1914. Professor Works received his training at the University of Wisconsin, and has had several years experience as teacher and principal in high schools and three years as superintendent of schools. Professor Works took up his duties here as head of the Department of Rural Education on July 1.

Professor Rollins Adams Emerson, Ph.D., was appointed on June 15, 1914, Professor of Plant Breeding and head of the department in place of Doctor Webber, who resigned a year ago. Professor Emerson was graduated from the University of Nebraska in 1897, was horticulturist in the United States Office of Experiment Stations in 1897 and 1898, and was appointed Assistant Professor of Horticulture at the University of Nebraska in April, 1899, later being promoted to a full professorship. Professor Emerson has given special attention to work in plant breeding, and has done special work in this subject at Harvard.

Ralph Sheldon Hosmer, B.A.S., M.F., was appointed Professor of Forestry in charge of the department on June 15, 1914. He takes the place of Professor Mulford, resigned. Professor Hosmer received his training at Bussey Institution and Lawrence Scientific School at Harvard. He then spent some time in the United States Forestry Service, and since 1903 has been superintendent of forestry in the Territory of Hawaii. He received the degree of Master of Forestry from the Yale Forest School in 1902. He will take up his new duties with the beginning of the next academic year on October 1.

Sabbatic leaves of absence have been granted to Professors Lyon, Whetzel, Cavanaugh, and Warren for a whole or a part of the present academic year.

Early in the year Professor Walter Mulford, head of the Department of

Forestry, tendered his resignation, which was accepted by the Trustees at their meeting on May 2. Professor Mulford has been exceptionally successful in his work here, and his departure means a distinct loss to the College and to the forestry work in New York State.

With the close of the current academic year, Professor John Henry Comstock retired from active service and was appointed Professor Emeritus at the June meeting of the Board of Trustees. For over forty years Professor Comstock has given active and loyal service to Cornell University. Beginning as an undergraduate assistant in charge of a special course in entomology, he has developed a department of world-wide reputation. It is impossible to measure the influence of his work. Beginning at a time when the science of entomology was almost unknown in this country, he has established standards of education in the applied phases of the subject, insisting always that a broad training in the pure science must precede and underlie the practical applications. The result has been that his students have been among the foremost leaders in the development of all branches of entomology. More than a hundred of them have been teachers or have held important positions in national and state departments of entomology in this and foreign countries. Professor Comstock's own research in both the pure and the applied science has been fundamental and has won international recognition. Fortunately we are not to lose his influence and his counsel, for, as Emeritus Professor, he is to retain his private room in the Department of Entomology and will there bring to completion some of the important researches and textbooks that he has under way.

COLLEGE BUILDINGS

By action of the Board of Trustees on recommendation of the Faculty of Agriculture, the main administration building has been named Roberts Hall, in recognition of the long and faithful service rendered by Professor I. P. Roberts as Director of the College.

The new auditorium has similarly been named Bailey Hall, in honor of Director Bailey.

During the year considerable progress has been made in the erection of buildings in accordance with the ten-years plan for the development of the College of Agriculture which was approved by the Board of Trustees in 1910. The new auditorium (now Bailey Hall) was practically completed and occupied during Farmers' Week in February, 1914. The College of Agriculture has had no assembly hall of sufficient size for general gatherings of students and Faculty. Bailey Hall will be of much value for this purpose, as well as for frequent meetings of farmers and for general university purposes.

The new Forestry Building is now completed and has been occupied

since May by the Department of Forestry. The building was informally opened on May 15 and 16.

The new Animal Husbandry Building and the Stock Judging Pavilion, situated east of the playground, are nearing completion and have been occupied since midsummer.

The new Agronomy Building is progressing rapidly and will be ready for occupancy about February 1.

Headquarters for the Department of Landscape Art have been provided by the removal and remodeling of the old central poultry building, which is now located at the northeast corner of the agricultural quadrangle. While this is an inexpensive building, somewhat temporary in its nature, it serves as very comfortable and satisfactory quarters for the Department for the present time.

For several years the increase in registration has been so rapid that it has been impossible to provide buildings for proper instruction. The registrations to date for next year indicate that the increase will continue. It is essential that we secure more buildings as quickly as possible. The ten-years plan for the development of the College of Agriculture, which was approved by the Board of Trustees in 1910 and accepted by the Legislature, should be worked out as rapidly as possible. The building most needed at the present time is for some of the plant industry departments. Several departments are now housed in quarters entirely inadequate and not at all suited for the types of work they are trying to do. For some years to come, one of the most important problems for the College of Agriculture will be to provide adequate accommodations for instruction.

THE EDITORIAL WORK

During the year 1913–1914, a volume of one hundred and forty-eight pages, entitled *The Buildings, Lands, and Activities of the New York State College of Agriculture at Cornell University*, was published. It is the successor to a small pamphlet published in 1909 entitled *A Guide to the New York State College of Agriculture at Cornell University*. In the present volume the attempt is made to describe succinctly the more general aspects of the buildings, lands, and activities of the College, and to provide at once a book which students may carry with them as they go over the farms, which will direct the constantly increasing number of visitors in their inspection of the College domain and will answer many of their questions, and which will provide a means of relief in answering certain types of correspondence. The volume is particularly valuable in helping to unify the many phases of the work of the College.

During the year there has also been inaugurated a series of Farm Bureau Circulars, the purpose of which is to make available complete and specific

information concerning the history and present status of agriculture in the various counties of New York State. In addition to giving a brief history of agriculture in the county considered, each circular will include a description of the local climate, soil, and topography; a statement of population, general business conditions, market facilities, and types of farming practiced; and tables showing total production and unit yields. It will also point out desirable systems of farm management, suggest changes that should be made, and call attention to many other important matters on which success in farming depends locally. A part of each circular will be devoted to an account of the local farm bureau, its organization, and its ability to help in developing the agriculture of the county. The circulars will be prepared by the several county farm bureau agents under the general direction of the State Director of Farm Bureaus. Three of these circulars have already appeared, and a fourth is in preparation.

Following is a summary statement of the editorial business of the College from October 1, 1913, to September 30, 1914. The total number of separate publications issued, not including discussion papers that accompany the Reading-Course Lessons, is eighty-four; the number of printed pages is 4851; the number of printed copies issued is 3,014,000.

REPORT ON EDITORIAL WORK

October 1, 1913, to September 30, 1914

BULLETINS:	Number of pages in printed bulletin	Number of copies printed
336 Distribution of moisture and salt in butter	24	8,000
337 The Babcock test, with special reference to testing cream	24	15,000
338 An examination of some more productive and some less productive sections of a field	68	4,300
339 Experiments concerning the top-dressing of timothy and alfalfa	28	20,000
340 Experiments in the dusting and spraying of apples	36	15,000
341 Crop yields and prices, and our future food supply	32	40,000
342 Sweet-pea studies — IV. Classification of garden varieties of the sweet pea	148	15,000
343 Oats for New York	56	13,000
344 Agricultural surveys	20	7,000
345 A continued study of constitutional vigor in poultry	24	45,000
346 The tarnished plant-bug	68	5,000
347 Endothia canker of chestnut	92	10,000
348 A bibliography of the writings of Professor Mark Vernon Slingerland	32	5,000
349 Some important factors for success in general farming and in dairy farming	52	40,000
350 Potato scab and sulfur disinfection	40	7,000
351 Soil survey of Orange County, New York	56	3,000
352 Effects of variations in moisture content on certain properties of a soil and on the growth of wheat	68	5,000
Total	868	257,300

MEMOIRS:	Number of pages in printed bulletin	Number of copies printed
No. 3 Variation and correlation of oats (Avena sativa). Part I. Studies showing the effect of seasonal changes on biometrical constants	72	7,000
No. 4 Variation and correlation of oats (Avena sativa). Part II. Effect of differences in environment, varieties, and methods on biometrical constants	144	5,000
Total	216	12,000

CIRCULARS:		
No. 21 The yellow-leaf disease of cherry and plum in nursery stock	12	15,000
(No. 16) (Supplement) The improved New York State gasoline-heated colony-house brooding system	4	17,000
No. 22 Wholesale prices of apples and receipts of apples in New York City for twenty years	8	20,000
No. 23 Outline of the function and use of commercial fertilizers	8	10,000
No. 24 Some suggestions for city persons who desire to farm.	12	40,000
No. 25 Outline of the relation of the use of lime to the improvement of the soil	12	10,000
No. 26 Peach cankers and their treatment	12	20,000
Total	68	132,000

READING-COURSE LESSONS FOR THE FARM:		
50 Nature, effects, and maintenance of humus in the soil	28	50,000
Supplement	4	(50,000)
52 Culture of the blackberry	16	25,000
Supplement	4	(25,000)
54 The dairy herd	20	30,000
Supplement	4	(30,000)
56 Practical horse-breeding	32	35,000
Supplement	4	(35,000)
58 Planting the home vegetable garden	20	40,000
Supplement	4	(40,000)
60 Farm butter-making	16	35,000
Supplement	4	(35,000)
62 Methods of determining the value of timber in the farm woodlot	32	55,000
Supplement	4	(40,000)
64 The rural school and the community	48	70,000
Supplement	4	(60,000)
66 Meadows in New York	16	40,000
Supplement	4	(35,000)
68 Improving the potato crop by selection	20	30,000
Supplement	4	(25,000)
70 Soil moisture and crop production	24	50,000
Supplement	4	(45,000)
72 Culture of the grape	20	30,000
Supplement	4	(25,000)
Total	340	*490,000

*Supplements not included, as printed with lessons.

	Number of pages in printed bulletin	Number of copies printed
READING-COURSE LESSONS FOR THE FARM HOME:		
49 Household insects and methods of control	48	50,000
Supplement	4	(50,000)
51 A story of certain table furnishings	24	45,000
Supplement	2	(45,000)
53 The Christmas festival	12	45,000
Supplement	2	(45,000)
55 Rice and rice cookery	20	45,000
Supplement	2	(45,000)
57 A syllabus of lessons for extension schools in home economics	44	25,000
Supplement	2	(25,000)
59 Sewage disposal for country homes	40	60,000
Supplement	4	(60,000)
61 Attic dust and treasures	16	50,000
Supplement	4	(50,000)
63 The young woman on the farm	8	50,000
Supplement	8	(50,000)
65 Farmhouse amusements for girls and boys	44	55,000
Supplement	4	(55,000)
67 Canning clubs in New York State.— Part I. Organization	8	50,000)
Supplement	4	(50,000
69 Canning clubs in New York State.— Part II. Principles and methods of canning	20	50,000
Supplement	4	(50,000)
71 Canning clubs in New York State.— Part III. Canning equipment	12	50,000
Supplement	2	(50,000)
Totals	338	*575,000
RURAL SCHOOL LEAFLETS:		
November, 1913	28	200,000
January, 1914	28	200,000
March, 1914	48	200,000
April, 1914	40	20,000
September, 1914	276	55,000
Total	420	675,000
ANNUAL REPORT FOR 1913 (in two volumes)	2,032	2,000
ANNOUNCER:		
October issue	4	62,000
November issue	4	62,000
December issue	4	64,000
January issue	4	64,000
February issue	4	74,000
March issue	4	64,000
April issue	4	69,000
May issue	4	75,000
June issue	4	56,500
July issue	4	59,000
August issue	4	61,000
September issue	4	61,000
Total	48	771,500

* Supplements not included.

	Number of pages in printed bulletin	Number of copies printed
ANNOUNCEMENTS:		
Summer Session (six weeks)	13	*25,000
Summer term (third term)	22	3,500
Regular Announcement of Courses	70	20,000
Winter Courses	38	9,000
Forestry	20	3,500
Total	163	61,000
FARM BUREAU CIRCULARS:		
No. 1 Farm bureaus: what they are and how they are organized and financed in New York State	8	5,000
No. 2 Broome County: an account of its agriculture and of its farm bureau	16	6,000
No. 4† Jefferson County: an account of its agriculture and of its farm bureau	20	8,000
Total	44	19,000
EXTENSION CIRCULARS:		
No. 5 Concerning the supervision of advanced registry records	4	5,000
No. 8‡ Floriculture at Cornell University	8	2,000
Total	12	7,000
MISCELLANEOUS:		
The buildings, lands, and activities of the New York State College of Agriculture at Cornell University, Ithaca, New York	148	5,000
Notes for the guidance of authors	8	500
School for leadership in country life	14	2,500
Handbook of information for students	32	1,200
Director's report to President	§20	....
Proceedings at the opening of the Forestry Building	70	3,000
Total	292	12,200

Work handled during September, to be printed after September 30

READING-COURSE LESSONS:		
(Farm Home)		
No. 73 Making cake.— Part I	20	50,000
Supplement	2	(50,000)
(Farm)		
No. 74 Introduction to the principles of soil fertility	16	50,000
Supplement	4	(45,000)
No. 76 Birds in their relation to agriculture in New York State	40	50,000
Supplement	4	(45,000)
Total	86	¶150,000

* Combined with Announcement of University Summer Session.
† Farm Bureau Circular No. 3 did not go through the Editorial Office.
‡ Extension Circulars 6 and 7 did not go through the Editorial Office.
§ Approximate.
¶ Supplements not included.

Summary

	Total number	Total pages	Copies printed
Experiment Station bulletins*..................	15	820	234,300
Bulletins 336 and 337 (copies handled by mailing room after October 1, 1913)................	....	....	23,000
Experiment Station memoirs....................	2	216	12,000
Experiment Station circulars....................	6	64	115,000
Supplement (to Circular No. 16)	1	4	17,000
Reading-Course for Farm.......................	12	292	490,000
Supplements to Reading-Course for Farm.........	†(12)	48	‡(445,000)
Reading-Course for Farm Home............... .	12	296	575,000
Supplements to Reading-Course for Farm Home...	†(12)	42	‡(575,000)
Rural School Leaflets§.	4	392	475,000
November Rural School Leaflet (copies handled by mailing room after October 1, 1913).......	....	....	200,000
Annual Reports...............	1	2,032	2,000
Announcers................	12	48	771,500
Announcements.............	5	163	61,000
Farm Bureau Circulars..................	3	44	19,000
Extension circulars.....	2	12	7,000
Miscellaneous....	6	292	12,200
Publications handled during September, to be printed after September 30....	3	86	....
Grand totals..........................	84	4,851	3,014,000
Plus supplements omitted, as indicated above.....	24		1,020,000
	108		4,034,000

* Not including Bulletins 336 and 337, which were included in the preceding annual report.
† Not counted in grand total number of separate publications issued.
‡ Not included in grand total of copies printed, as printed with lessons.
§ Not including November (1913) Leaflet, which was included in the preceding annual report.

FUTURE OF THE COLLEGE

The future of the College of Agriculture is bright. Its relations with the other educational institutions of the State are harmonious and the outlook is altogether encouraging. The writer has no definite policies to announce at this time, believing it the part of wisdom to develop plans further before making any statement as to what these plans involve. Some important changes are taking place in connection with our extension work, especially since the passing of the Lever Act. Important changes are taking place in regard to cooperative relations with the Education Department of the State, the secondary schools, and the State Department of Agriculture. These matters will be fully discussed as soon as plans now being formulated are in full operation.

Respectfully submitted,

BEVERLY T. GALLOWAY,

Director of the State College of Agriculture.

STATEMENT OF STATE MAINTENANCE APPROPRIATION
1913–1914

October 1, 1913, appropriation, $450,000

Expended as follows:

Administration	$ 85,734.53
Floriculture	3,528.07
Entomology	1,728.79
Farm Practice	15,994.08
Farm Management	2,125.37
Soils	1,882.51
Vegetable Gardening	1,514.26
Plant Pathology	4,038.02
Vegetable Gardening equipment	1,242.64
Forestry	1,265.11
Pomology	2,248.08
Rural Education	1,439.48
Rural development	540.86
Dairy Industry	11,219.63
Library	724.28
Drawing	272.59
Salaries	260,419.11
Survey work	376.28
Home Economics	2,736.48
Chemistry	1,089.91
Rural Economy	1,402.52
School for Leadership	1,106.20
Entomology list fund	602.63
Animal Husbandry	11,416.73
Meteorology	111.21
Plant Breeding	1,865.25
Nursery investigation	170.05
Farm Crops	2,067.48
Extension	3,314.31
Botany	3,038.45
Rural Engineering	1,415.25
Landscape Art	1,508.17
Landscape Art Building	4,684.29
Poultry	5,469.91
Landscape Art equipment	1,163.96
Aquiculture	59.19
Greenhouse	1,372.57

Water supply	$ 7.95
Rural problems	10.38
Poultry-moving fund	84.47
Carpenter shop	1,124.89
Total	$442,115.94

Balance to meet purchase and obligations arranged for but not completed for payment to date, $7,884.060.

EXTENSION FUND

October 1, 1913, appropriation, $70,000

Expended as follows:

Vegetable Gardening	$ 307.87
Plant Pathology	1,047.09
Pomology	455.37
Extension	15,574.63
Salaries	39,727.05
Entomology	793.14
Administration	3,991.12
Poultry Husbandry	1,010.54
Forestry	632.64
Animal Husbandry	227.54
Dairy Industry	457.18
Rural Economy	443.98
Home Economics	2,109.44
Soil Technology	1,279.25
Floriculture	37.46
Farm Management	2.75
Total	$68,097.05

Balance to meet purchases and obligations arranged for but not completed for payment to date, $1,902.95.

EXPERIMENT STATION FUNDS, JULY 1, 1914

	Received	Expended
Hatch	$13,500	$13,500
Adams	13,500	13,500

Expended as follows:	Hatch	Adams
Salaries	$ 4,746.67	$ 8,388.01
Labor	2,446.19	1,952.82
Publications	107.28	....
Postage and stationery	1,506.21	151.40
Freight and express	107.26	13.62
Heat, light, water, and power	400.15	....
Chemicals and laboratory supplies	452.69	1,245.51
Seeds, plants, and sundry supplies	951.49	272.11
Fertilizers	156.30	5.60
Feeding stuffs	1.88	....
Library	61.27	69.07
Tools, machinery, and appliances	687.02	95.62
Furniture and fixtures	384.00	530.92
Scientific apparatus and specimens	295.75	493.80
Live-stock	....	....
Traveling expenses	782.20	44.67
Contingent expenses	....	....
Buildings and land	413.64	236.85
Total	$13,500.00	$13,500.00

No unexpended balance after September 30, 1914.

October 10, 1914

PROFESSOR B. T. GALLOWAY, *Director*, *College of Agriculture*, *Cornell University*, *Ithaca*, *New York:*

SIR:— Agreeably with the instructions received through your general office, we have made a thorough audit and examination of your books and accounts for the fiscal year beginning October 1, 1913, and ended September 30, 1914, and as a result submit herewith financial statement showing the actual receipts of cash by your office from the various departments and the accounts deposited with University Treasurer, made up in monthly amounts.

For your convenience we have made an analysis of these receipts showing the amount of cash received from each department.

We have also made a comparative statement of the receipts for the fiscal years ended September 30, 1913, and September 30, 1914.

You will observe that in the latter year the sum of $7616.87 is included for winter class fees paid to this office, which fees were formerly paid direct to the University Treasurer's office.

The receipts from the Dairy Department show a falling off of $10,731.61, as compared with last year, whilst Testing and Animal Husbandry show a gain of $18,050.22 as compared with the previous year.

Home Economics show a gain of $30,470.69 over last year, which was to be expected, as the department was in operation for only part of the year 1913–1914.

Poultry Co-operative Association shows a considerable falling off in receipts, but we are given to understand that this department has practically been given up.

The various other departments show fluctuating losses or gains, which no doubt can be satisfactorily explained by the officers of these departments.

We have verified the amounts as entered on your cash book with the duplicate copy of the original receipt as given to the department making the deposit, and we have further satisfied ourselves as to the accuracy of same by comparing these amounts with the original receipts held by the various departments.

We have verified all the footings on the cash book of receipts, and amounts deposited with the University Treasurer, and have found them to be absolutely correct.

We have also compared the amounts entered on the cash book as deposited with the University Treasurer, with the amounts as entered on his book as paid by this office, and we can certify as to the correctness of such entries.

We have verified the actual cash in the hands of your clerk and accountant, and find same to agree with the balance as shown on the cash book.

Every facility has been afforded to us in order to make this audit as thorough and complete as possible and any explanation required has been freely and satisfactorily given, and we are of the opinion that the statement attached hereto represents the actual cash received from all sources during the period covered by this audit.

We desire to say in conclusion that we found the books in first-class condition, the entries being neatly and correctly recorded, and with the increased receipts, and the large amount of detail in connection with this office, we have pleasure in testifying to the care and attention bestowed on the work on the part of your clerk.

Respectfully submitted,
(Signed) NATIONAL AUDIT COMPANY,
GEORGE WATSON,
Certified Accountant.

DEPARTMENT OF FARM MANAGEMENT

TEACHING

The courses in this Department were taken by the following numbers of students:

First term:		
Farm Management 1	181	
Farm Management 3	61	
Farm Management 4	34	
Graduate students	17	
		293
Second term:		
Farm Management 1	113	
Farm Management 2	187	
Farm Management 4	37	
Farm Management 5	1	
Graduate students	14	
		352
Winter course:		
Farm Management 1	158	
Farm Management 2	145	
		303
		948

A total of 2408 credit hours of instruction were given.

Because of the increasing number of students, courses 1 and 2 will hereafter be taught twice each year.

INVESTIGATION

Additional work has been done in tabulating the surveys of Jefferson and Livingston Counties, but owing to the pressure of teaching work the bulletins have not yet been prepared.

Professor Livermore is continuing the study of the most successful farms found by the survey method.

Professor Thompson has completed a study of the cost of producing milk for two years on 174 farms in Delaware County. This is now ready for publication.

Cost accounting work is being continued and increased. Accounts are now being kept on 58 farms.

Publications of the Cornell University Agricultural Experiment Station from this Department during the past year were:

Circular No. 22, "Wholesale Prices of Apples and Receipts of Apples in New York City for Twenty Years," by H. B. Knapp. This was prepared as a minor thesis for the degree of master of science.

Circular No. 24, "Some Suggestions for City Persons Who Desire to Farm," by G. F. Warren.

Bulletin 341, "Crop Yields and Prices, and our Future Food Supply," by G. F. Warren.

Bulletin 344, "Agricultural Surveys," by G. F. Warren.

Bulletin 349, "Some Important Factors for Success in General Farming and in Dairy Farming," by G. F. Warren.

EXTENSION

This Department received no funds for extension work. However, the cost accounting work is also extension work. Many letters have been answered, some lectures have been given, and a large amount of time has been spent in giving advice to persons who come to the College to consult on farm questions. This advising work now takes about half the time of the head of the Department. The kinds of questions about which advice is sought are of a most varied nature. Some are individual problems, many are problems dealing with education, county agent work, and public questions.

RECOMMENDATIONS

A further extension of cost accounting and survey work should be made. The latter might now be of a much broader nature than that thus far conducted. An extensive investigation of marketing of farm products should be begun.

G. F. WARREN,
Professor of Farm Management.

3

DEPARTMENT OF FARM CROPS

TEACHING

The number of students in the various courses in the Department of Farm Crops for 1913–1914 is shown by the following table:

Course	Subject	Number of students registered	Total hours credit
1	Cereals, Forage Crops, and Miscellaneous Crops.	113	452
2	Cereal Crops	43	172
3	Forage Crops	103	309
4	Potatoes, Beans, and Special Crops	66	132
	Summer term	26	54
		351	1,119
Post graduate			
	Graduate seminar	10	
	Candidates for degree of Master of Science in Agriculture.	4	
	Candidates for degree of Doctor of Philosophy	5	
		19	

INVESTIGATION

The Department is not yet equipped to carry on investigative work. Such work has been started in a small way with a few forage crop problems in the economic garden, as follows:

1. Relation of time and frequency of cutting on yield and duration of forage crops.

2. The cumulative effect of different forms of fertilizer on the character and quality of herbage.

3. Relative lime requirement of different legumes.

Graduate students under the direction of the Department are also working on the following problems:

1. *Potato survey of New York State.*— About 1300 records have been taken in the chief potato-growing sections.

2. *Classification of American varieties of oats.*— About 700 varieties are under culture.

EXTENSION

The Department has not been able to take an active part in extension enterprises. During the past year members of the Department assisted at several boys' corn and potato shows; a potato show was held during Farmers' Week; assistance was given at several potato field meetings; help was furnished for four weeks with educational trains, at two county fairs, and at one state fair.

E. G. MONTGOMERY,
Professor of Farm Crops.

DEPARTMENT OF FARM PRACTICE

The Department of Farm Practice is unique among the departments of the College in that it has less teaching, investigative, and extension work to do, and many more administrative duties, than most departments.

TEACHING

The teaching work is practically confined to the course in Farm Crops in the Winter Course in Agriculture, in which 299 persons were registered last winter.

In the announcement issued by the College, the one course offered by this Department is listed as "an elective course designed to assist students in meeting the requirements in farm practice demanded by the College." This matter will be discussed in the last division of this report.

INVESTIGATION

The investigative work of the Department consists chiefly in taking note of the durability of various roofing materials used on the farm buildings; the durability of several types of wire fencing and of fence posts; the effect of tile drains in several parts of the college farm; the adaptation of varieties of corn for producing silage in the vicinity of Ithaca; methods of starting alfalfa fields; and the use of nitrate of soda on timothy meadows.

Records are kept, by fields, of all labor bestowed on crops and of crop yields, so that it is possible to make a detailed study of crop production. Owing to pressure of other work, however, it is not possible to keep the data thus obtained in a form available for ready reference.

EXTENSION

The Department of Farm Practice has no funds especially set apart for extension work. Much of its work, however, falls into this class. The winter courses, in one of which the teaching previously mentioned is done, are now classed as extension work. The correspondence of the Department, which consists largely in answering letters of farmers, amounted to about 3000 letters during the past year.

Only three extension schools were attended during the past year, owing to the fact that they occur chiefly during the time when the winter courses are in session. Visits were made to twenty-four farms in order to investigate special problems and to advise with their owners regarding management. Addresses were delivered at nine meetings of farmers' clubs and granges.

ADMINISTRATION

During the past year this Department has done the farming on about 320 acres of land devoted to general crops — hay, corn, oats, wheat, rye, buckwheat, and roots — and has furnished most of the horse labor and a considerable part of the man labor employed on 180 acres of land used by the other departments of the College in their investigation, demonstration, and teaching. In conducting this work it has used ten to fourteen teams and twenty to thirty men. It has had the use of a tractor for considerable plowing and harrowing, and a motor truck for most of the freight and other hauling from town which the Department is called upon to do. During the winter the teams are largely used in hauling the coal for heating the university buildings. About 13,000 tons are handled in a year. During the winter the Department got out between 350 and 400 cords of wood for the Department of Forestry, and in the spring the Department planted about six thousand young forest trees.

The crops produced were

Crop	Area (acres)	Product
Hay	120	437 tons
Silage	50	522.5 tons
Roots	2	47 tons
Wheat	44	1,675 bushels
Oats	38	1,485 bushels
Rye	4	85 bushels
Buckwheat	34	586 bushels
Potatoes	7	1,860 bushels

IMPROVEMENTS

During the past year the work on farm improvements has been continued as rapidly as the demands of the other work would permit. About 7225 feet of tile were laid on the South Side Farm for this Department, and about 5330 feet in Caldwell Field for the Department of Soil Technology. The macadamizing by the State of the Ellis Hollow road along the south side of the farm gave us an opportunity to dispose of a large amount of stones that were scattered over the fields or lying in hedgerows. About 1200 large loads were delivered to the contractor at a price that practically covered the cost of clearing them from the land. We have also cleared away more than 100 rods of hedgerows from the Smith farm, which involved the removal of a half-century's accumulation of field stone and tree growth and required the use of a large amount of dynamite.

Much manure was drawn from the city, but a large proportion of it is used by other departments. The land farmed by this Department is now getting into such condition that before long it will not be necessary to use manure in excess of the amount produced on the farm, except on the south side. There are more than seven miles of roads bordering or crossing the college domain. As the University does not pay taxes, the city and town authorities do no more on these roads than they are compelled to do. The farm superintendent has approached these authorities on the subject, has attended some of their meetings, and has gained their cooperation in considerable road betterment by offering to contribute some labor of men and teams if they would undertake the improvements. This effort has resulted in better roads along the college domain. This Department has borne the expense of this work.

JOHN L. STONE,
Professor of Farm Practice.

DEPARTMENT OF PLANT BREEDING

TEACHING

The work of instruction to graduate and undergraduate students has grown rapidly during the past few years. The rate of increase in plant-breeding classes has been much greater than the rate of increase in the number of students in the College as a whole. The accompanying table shows the increase in the number of students in undergraduate classes, and in the number of university hours taught, since the beginning of the work of instruction in plant breeding in 1908. These figures do not include graduate students or short-term students.

Year	Term	Number of students registered	Total number of students registered	Number of hours university credit	Total number of hours university credit
1908–1909	First	37		111	
	Second	27	64	81	192
1909–1910	First	58		174	
	Second	33	91	99	273
1910–1911	First	109		327	
	Second	46	155	92	419
1911–1912	First	133		399	
	Second	53	186	106	505
1912–1913	First	134		391	
	Second	87	221	248	639
1913–1914	First	355		630	
	Second	88		241	
	Third	27	470	470	1,341

The number of students taking graduate work in this Department has always been very large and is gradually increasing. Approximately one hundred persons have been registered as graduate students in our laboratories up to last year, and there are about thirty at present.

Our removal to new and enlarged quarters has greatly facilitated our work in every direction

This Department offered summer courses for the first time during the summer of 1914. These courses were very successful. The opportunities of getting instruction out of doors among the growing plants added much to the students' knowledge of breeding processes.

A. W. GILBERT,
Professor of Plant Breeding.

INVESTIGATION

The experiments conducted by the Department of Plant Breeding have been continued during the past year along the lines given in previous reports. New experiments are to be added, due to the fact that Professor R. A. Emerson has been made head of the Department and will move his research experiments from the Nebraska Experiment Station to this Station.

Research under the Adams Act

A study of the laws of inheritance in hybridization.— The experiments under this subject have been enlarged in the past year. Some of the hybrids of oats have now been followed to the third generation, and the first-generation hybrids of wheat were grown in the greenhouse this past year and are now growing in the second generation. These studies are affording many interesting data.

The experiments with the morning-glory have also been continued. Some of these studies have been brought together and they show very interesting results regarding color inheritance in the morning-glory.

A study of mutations and variations in relation to breeding.—The pure-line studies under this subject have been continued during the past year with wheat, oats, phlox, beans, and potatoes. It is the purpose of this experiment to determine what effect, if any, may be produced by selecting within the pure lines of the various species mentioned. The studies in the inheritance and correlation of characters and bud variation in timothy have been continued and enlarged during the past year. Many data are being collected on the different types of timothy now growing, in order to show the behavior of the characters distinguishing the different types.

The study of potatoes in order to show the amount of variation within the various pure lines has been enlarged during the past year, and continued along the same general lines as are outlined in previous reports. Many statistical records are being collected in order to show the amount of variation occurring within these various pure-tuber lines.

New work under this topic added the past year has been that with clover. The purpose of this work is to determine the amount and nature of variation that occurs in clover, and to study the effect of selection

on this variation. The inheritance and correlation of characters are also being studied.

Influence of environment in producing variations of importance in species and variety formation.— The environmental studies dealing with daisies, wheat, and peas are still being continued. The study with daisies consists of taking notes on the variation of the number of ray florets from plants grown under very different conditions. Plants growing on hilltops, in valleys, and under normal conditions, are being studied. Data are also being collected on a certain lot of daisies, the material being collected daily from the beginning to the end of the blooming season. These data have been collected for five years, and they afford material for studying the variation within a single season and also the seasonal variation for the different years.

The studies with wheat and peas consist in growing these crops in plats possessing different degrees of fertility. One of these plats is composed of poor soil, and the other of ordinary soil very highly fertilized. Statistical notes are collected on the crops; these show the effect of the different degrees of environment on the crops. Seed is also collected from the poor and the rich soil plat, and then grown on soil possessing the same degree of fertility in order to determine whether any permanent change has been effected.

Experiments are being conducted in cooperation with the Montana Agricultural Experiment Station and the Missouri Agricultural Experiment Station. With the Montana Station an experiment with oats is being conducted, in which the same pure line of oats is being grown at that station and at Ithaca. Statistical notes are being taken in order to observe any change in growth and in the variation and correlation of characters at the different places. Seed is to be exchanged in order to see whether there is to be any permanent effect. The experiment with the Missouri Station is along the same lines, but wheat is the crop used in this case.

Research under the Hatch Act

Breeding cereals.— The breeding work with corn, wheat, oats, and barley is being continued and enlarged. The corn-breeding plats at Ballston Lake, Aurora, and Bedford Hills are being continued. Seed is selected for both amount of yield and early maturity at these places. At all these places a change in earliness has been made, so that the corn matures at least two weeks earlier than did that from the seed with which we started in 1908.

The experiments with oats have consisted in further testing some of the early selections and hybrids that have been made, and comparing these with the common commercial varieties. New selections have been

added this past year, some of which give indications of being superior to many of the selections already under trial. Hybrids are also being made in order to attempt to combine the good qualities possessed by certain types into one type.

The experiments with wheat have been enlarged this past year by the addition of many new selections that have been made from the common varieties grown in various parts of New York State. These are being compared with the commercial varieties now grown.

The experiments with barley are merely preliminary, in that the work consists in an attempt to find what varieties or types of barley are best adapted to New York conditions. A large number of varieties have been tested this past year.

In addition to these tests, studies have been made in order to determine the best methods to be used in breeding cereals, and much time has been given to ways and means of facilitating the handling of a large number of necessary tests. Much has been done in the planning and arranging of machinery for this sort of work.

Breeding timothy.— The timothy-breeding work has been enlarged to some extent during the past year, mainly along the line of conducting further field tests of the new varieties. Additional broadcast plats have been sown, until now there are sixty varieties of timothy in this test. The oldest series of these plats are now four years old and the results are becoming valuable. More definite information will soon be available regarding the merits of the most promising of the new varieties.

For the purpose of testing the varieties under conditions different from those at Ithaca, six additional cooperative experiments have been planned with farmers in various parts of the State. This is deemed an important part of the work. Varieties that do well at Ithaca will not necessarily be the best for certain other communities. It is only by such cooperative tests that these facts can be ascertained, but under the present organization it will not be possible to extend this particular part of the work.

Breeding potatoes.—The potato-breeding work has been enlarged to some extent during the past year. In connection with the bud-variation study, certain high-yielding lines have been isolated by individual selection. In order that these lines might be compared with one another and with commercial varieties, a variety test has been conducted which includes some thirty commercial varieties from various sources and six pure-tuber lines from the pedigree cultures. A few of the commercial varieties have given a heavier yield than the pure-tuber lines. However, when the proportion of marketable potatoes in the different lots is considered, the evidence is in favor of the new lines, since the tubers of these are much more uniform and of better quality. One year's results are available

so far. but it will be necessary to continue the test for three to five years before definite information can be obtained.

The comparison of yields from the basal and apical ends of individual tubers is still being made. An average of five years with twenty-one varieties has shown that the apical ends outyield the basal ends by twenty-seven bushels per acre. Last year and the year before, the number of stems produced in each series was counted. The purpose of this was to see whether the additional yield from the apical end is due to the fact that a larger number of stems are produced from that end than from the basal end.

H. H. LOVE,
C. H. MYERS,
Professors of Plant Breeding.

EXTENSION

Since October 1, 1913, the Department of Plant Breeding has had no extension funds. However, the cooperative breeding work and seed distribution have been done on Hatch and State funds allotted to the Department. Very little has been done to increase this part of the work. It has been the aim to maintain the work begun with the extension funds allotted in the years 1911 to 1913.

During the past year there have been established seven cooperative wheat-breeding plats and six timothy-breeding plats. No additional work has been started with corn, oats, or potatoes.

In connection with the distribution of seed, sixty-three samples of oats, twenty-five samples of timothy, and eight samples of wheat, have been distributed. In each case the Department furnished detailed instructions for the handling of this seed, and it endeavors to keep in touch with the persons to whom seed is sent to the end that the seed may become available in commercial quantities for the farmers of the State.

No corn has been distributed during the past year, but it is the intention of the Department to distribute a limited quantity of seed the coming year.

The exhibit and demonstration work during the past year has been handled largely by cooperation with other departments in the College or with outside sources. From October 27 to November 15, 1913, two plant-breeding demonstration cars were equipped with exhibit material illustrating the methods and results of plant-breeding work. These cars were run over the New York Central lines, on the Mohawk Valley and the Rome, Watertown, and Ogdensburg Division. Forty-two stops were made, with an average attendance of one hundred and forty-seven persons at each stop. From the 2d to the 13th of March, 1914, this

Department cooperated with the Departments of Farm Crops and Agricultural Chemistry in equipping a demonstration car to be run over the Lehigh Valley lines. Seventeen stops were made, with an average attendance of forty-three persons at each stop.

A large part of the plant-breeding exhibit was combined with exhibits from the Department of Farm Crops and the Rural Community Exhibit, and installed at the National Corn Show held at Dallas, Texas, February 10 to 24, 1914. The entire plant-breeding exhibit was installed at the Jefferson County Fair August 25 to 28, and at the State Fair August 31 to September 5. In all this work representatives of the Department were on hand to demonstrate and explain the exhibits.

C. H. MYERS,
Professor of Plant Breeding.

RECOMMENDATIONS

Clonal selection.— Tuber selection of potatoes has given such pronounced results, and bud selection of timothy so much of promise, that it is proposed to inaugurate similar investigations with several other crops, particularly with the apple and perhaps some other tree fruit, with the strawberry, and with some floricultural crop, such as the violet, the rose, or the carnation. In fact it seems desirable to make this a leading line of investigation for some years to come.

The possible value of scion selection in apples is a much-debated question among pomologists and nurserymen at the present time. While some data have been collected that give promise of important results, they are not of a nature to carry complete conviction among scientific men and not sufficient in extent to be used as a basis of specific recommendations to apple propagators. Since final results of investigations of this sort with such a crop as apples cannot be expected for a considerable number of years, and since the work must be carried out on a considerable scale, it is important that it be begun at an early date and that particular care be exercised in formulating plans for it.

While a thorough investigation of clonal selection with florists' flowers is not necessarily the long-time problem that apple-scion selection is, it will, nevertheless, require considerable time and a range of commercial greenhouses for its proper conduct.

In the case of both orchard and cut-flower crops, therefore, it seems wise that the investigations be conducted cooperatively by the Departments of Plant Breeding and Pomology in one case, and by the Departments of Plant Breeding and Floriculture in the other. Preliminary steps have already been taken looking toward such cooperation.

Biochemical and cytological investigations.— Among the new lines of work

which the Department should undertake and for which funds should be allotted as soon as possible, are certain biochemical-genetic and cytological-genetic investigations. The study of color inheritance has now reached a stage in which thoroughgoing researches in the chemistry of color development are necessary for a full understanding of the phenomena of color genetics. It would be of the greatest importance to genetics to be able to connect known genetic factors with definite chemical substances or with particular stages in chemical reactions. Material, certain genetic factors of which have been identified, is available. The expense involved in the investigation would be that of equipping a small chemical laboratory and of providing a competent biochemist.

There is a similar need for careful histological and cytological studies in connection with some of the genetic problems under investigation in this Department. Certain rather diverse types of partial or total sterility occurring both in hybrids and in selfed strains await cytological study. Questions are continually arising in connection with the investigation both of color and of size inheritance, which must be handled by a trained histologist. The plant-breeding laboratory is fairly well equipped for such work. The expense connected with such studies would, therefore, come principally from providing a competent man for the work.

It is quite possible that both the chemical and the cytological investigations suggested here could be conducted more economically in connection with the Departments of Chemistry and Botany, where much of the necessary equipment is at hand. It is possible, also, that the work could be more successfully prosecuted under the environments of these departments than in a plant-breeding department. It is certainly true, however, that, while the men employed for these lines of work must be primarily chemists and cytologists, they must also be well-trained genetists, in order to have constantly before them the genetic aspects of their problems. It may come about that these problems can best be handled cooperatively between the Departments of Plant Breeding and Chemistry and the Departments of Plant Breeding and Botany, respectively.

Nonresident lecturers.— It is very desirable that provision be made to bring before our students prominent nonresident specialists in various phases of genetics. Graduate students are now gathered here from all parts of the country for plant-breeding work. They should be given an opportunity to come in touch here each year with a few of the leading American and foreign genetists.

Extension work.— The extension activities should be greatly enlarged by this Department at the earliest possible date. A man who could devote his time wholly to extension should be added to the departmental staff. He should represent the Department before the public, have charge of the

distribution of improved cereals, forage crops, potatoes, and so forth, that may from time to time be developed in connection with our experiment station projects, and conduct cooperative breeding plats in various parts of the State. Ultimately more than one man will be required for this work. It is not to be expected that a single man can become sufficiently familiar with the practical breeding of the numerous cereals, forage crops, vegetables, and fruits which have prominent places in the agriculture of this State and for help in the improvement of which insistent demands are being made. Here, as in the case of some of the new lines of investigation suggested earlier in these recommendations, it may be feasible to carry out the work in part by cooperation with other departments of the College.

Botanic-genetic garden.— This Department feels the need of a well-organized botanic garden in which the genetic side is strongly emphasized. This garden should contain a large collection of native and foreign species of plants. Of even greater importance to this Department, there should be included any prominent variations of these species found in the wild state, as well as a select list of their cultivated forms. Special effort should be made to maintain in this garden the classic materials of modern genetic studies, such as Œnothera collections, variations and hybrids representing Mendel's experiments with peas, and so forth. Such a garden would furnish instructional and investigative materials of the greatest value to this Department. Moreover, there is scarcely a department in the College, related in any way to plant industry, that would not find a garden of this sort one of the important parts of its equipment.

R. A. EMERSON,
Professor of Plant Breeding.

DEPARTMENT OF BOTANY

In October, 1913, a new Department of Botany was organized in the College of Agriculture, and the previously existing Department of Plant Physiology was united with it. The present annual report is, therefore, the first report of this new Department.

The new Department has been housed during the year in the quarters vacated by the Department of Plant Pathology in the Agronomy Building. These quarters proved too small and too poorly lighted for class work. Because of the lack of space and equipment, only the required courses was given in the newly created phase of the Department. The following is an abstracted report of the work of the year:

TEACHING

The following table indicates the courses given, the number of students, and the number of credit hours of work done:

Course	Subject	Number of students registered			Number of hours credit		
		First term	Second term	Third term	First term	Second term	Third term
1......	General Botany...........	365	310	......	1,095	930	......
2......	Forest Botany............	12	....	.....	36	....	......
6a.....	Taxonomy of the Higher Plants.......	... .	.... ..	18	.. .	....	90
20.... .	General Plant Physiology..	15	70	.... .	60	280	......
21-a & b	Advanced Plant Physiology	......	....	2	....	....	20
21.....	Advanced Plant Physiology	23	19	....	92	76	.....
31......	Seminar in Plant Physiology	19	19	... .	19	19	......
		434	418	20	1,302	1,305	110
Summer school							
A.....	Elementary Botany.......	...	19	...	.....	57	......
B.....	Elementary Morphology of Seed Plants.........	... .	14	..	.... ..	14	......
C....	General Plant Physiology	......	8	.... .	....	32	......
D....	Identification, Classification, and Ecology of the Higher Plants and Ferns.	.....	21	.....	.....	42	......
E.....	Trees and Shrubs.........	......	14	... .	.... .	28	......
F.....	Methods of Teaching Elementary Botany........	......	7	.....	.....	0	......
G.....	Research for Graduate Students..............	......	2	.....	......	....	.....
		......	85	......	......	173+	.....

Graduate students

Major, Doctor of Philosophy	7
Minor, Doctor of Philosophy	25
Major, Master of Arts	6
Minor, Master of Arts	2
Major, Master of Science in Agriculture	1
Minor, Master of Science in Agriculture	2
	43

The number of students doing research work was eleven, and the approximate number of hours research was three hundred and fifteen.

The instructing staff consisted of one professor, one assistant professor, seven instructors, and seven assistants, making a total of sixteen. The staff was not sufficient to instruct the large number of students in the introductory course. All the teachers were overworked, and had almost no time for their own research and necessary reading. There was not sufficient help to properly build up the required equipment and laboratory materials.

INVESTIGATION

The number of persons engaged in investigation during the year (staff and graduate students) was approximately twenty-five. The following research was brought entirely or almost entirely to a conclusion, and is exclusive of many other problems that are under way:

H. M. Benedict. Senile changes in the leaves of Vitis.

M. J. Prucha. Physiological studies of *Bacillus radicicola* of Canada field peas.

J. K. Wilson. Physiological studies of *Bacillus radicicola* of soy bean.

T. S. Kuo. The influence of certain salts on the development of nodules on vetch.

J. K. Wilson. Seed sterilization.

Some of the unfinished problems are:

W. J. Robbins. Influence of inorganic salts on diastase production and secretion by certain fungi.

O. F. Curtis. Physiological studies on the production of roots by plant cuttings.

R. S. Nanz. Secondary thickening and bud development of apple.

Lewis Knudson. The direct absorption by means of roots and the assimilation of carbohydrates by green plants.

F. P. Metcalf. Preparation of an analytical key to the species of grasses based on vegetative characters.

H. A. Severy. Preparation of an analytical key to the families of cultivated plants.

L. A. MacDaniels. Preparation of an analytical key to wild woody plants, based on anatomical characters.

EXTENSION

The extension work of the Department has been confined largely to correspondence, a considerable part of which has been concerned with problems of legume inoculation. As a part of this extension work, the Laboratory of Plant Physiology has sent out approximately six thousand cultures to one thousand farmers for the inoculation of legumes. Exhibits were made during Farmers' Week and also at the State Fair at Syracuse. In cooperation with the School of Agriculture at Alfred University and with a number of farm bureau managers, exhibits relating to legume inoculation were provided for several of the smaller fairs. Three lectures on legume inoculation were given in Farmers' Week. The Department prepared also a weed exhibit for Farmers' Week, and a demonstration of the preparation of slides for the microscope. A lecture on weeds was also given. During the year approximately two hundred letters have been written in reply to queries from farmers and others asking for the identification of weed samples and for information in regard to their extermination. This weed correspondence is becoming an important part of the work of the Department.

RECOMMENDATIONS

The Department is now very poorly housed. Every room is occupied nearly all the time with laboratory sections or with recitations, leaving no space for even a preparation or work room. Some of the preparation work is being done in the Forestry Building, through the courtesy of the Department of Forestry. On two afternoons of the week two sections doing different work are forced to occupy the same room. For the work other than in plant physiology, there is no well-lighted laboratory suitable for microscopic work. Six sections of the introductory course now meet at one time.

The staff is inadequate for the present amount of instruction, and will be much more inadequate as the advanced courses are started this year. The influx of graduate students, and the decision of several departments to require some of the advanced laboratory courses in botany as prerequisites for their work, make it imperative that these advanced courses be provided for at once.

The Department is greatly in need of a conservatory containing illustrative plants to be used in connection with various phases of botany. At present it is almost impossible to have any living plants in lecture or laboratory rooms; it is quite impossible in cold weather.

The Department needs a small botanical garden in which may be found at least the common illustrative material used in botanical instruction.

K. M. WIEGAND,
Professor of Botany.

DEPARTMENT OF PLANT PATHOLOGY

TEACHING

During the year 1913-1914 instruction has been offered in twelve regular courses, including two courses in the summer school, two in the summer term, and one in the winter course. The teaching staff has consisted of eleven members, an increase of three over last year. The total number of students registered for the various courses was 291, of whom 6 were in the summer school, 14 in the summer term, and 92 in the winter course. There is a slight decrease from last year, but this is readily accounted for by the fact that the course in botany, which is prerequisite to courses in plant pathology, was changed from a freshman to a sophomore subject.

There were 22 graduate students registered in the Department for a major, and 7 for a minor, for the degree of Doctor of Philosophy. There were registered 1 student with a major, and 3 with a minor, for the degree of Master of Science. The advanced instruction and conferences with the graduate students have demanded the entire attention of the acting head of the Department.

INVESTIGATION

Marked progress has been made in a number of the various lines of experimentation and investigation. As usual, many of the investigations have been accompanied by field experiments. In eight cases, men have spent the growing season in a field laboratory where field and laboratory work have gone forward hand in hand.

Grape diseases.— Spraying experiments for the control of black rot were discontinued, owing to the extreme scarcity of the disease during the past few years. It now appears that the work could have been continued with profit, owing to the prevalence of the downy mildew disease, which could doubtless have been controlled by spraying.

The study of the downy mildew disease has been continued and is now practically concluded.

The work on the dead arm disease of grapes has been concluded and is published (New York [Geneva] Agr. Exp. Sta. Bul. 389).

Bean diseases.—As heretofore, the work has had to do chiefly with the anthracnose disease, and the lines of experimentation do not differ materially from those of former years. Some attention has been given to a serious and widespread root disease of beans, but no material progress has been made.

Nursery diseases.— Work with diseases of nursery trees has continued as outlined in the report of last year. The control of the yellow leaf

disease of cherries and plums has been perfected, and the methods to be employed are outlined in an experiment station circular (No. 21).

A study of the biological relations of the crown gall organism has been undertaken, and the "crown gall experiment" of previous reports has been incorporated in this much wider field of research.

Ginseng diseases.— Studies of ginseng diseases and their control have gone forward in cooperation with the State Ginseng Growers' Association and with the Division of Cotton and Truck Disease and Sugar-plant Investigations of the Bureau of Plant Industry, United States Department of Agriculture. An intensive study of the root rot disease has been made, and many additions to the knowledge of the causal organisms have resulted. Much of this work is now in preparation for publication.

Soil fungicides.— The experiments on the control of potato scab by applications to the soil of sulfur in varying quantities and combinations have been brought to a close. The results of the work have been published (Bul. 350 of this Station).

Experiments on the control of the smut disease of onions, and studies of the causal organism, will be brought to a close at the end of the present growing season, and a comprehensive report on the subject will be prepared for publication.

The use of dry fungicides.— The use of a dry fungicide for the control of apple foliage and fruit diseases has been continued on an extensive scale. A bulletin (Bul. 340 of this Station) has been published, and work now under way gives promise of yielding results suitable for a further contribution on the subject.

Forest-tree diseases.— The work on the chestnut-bark disease has been terminated and the results published (Bul. 347 of this Station).

A disease of chestnut oak (*Quercus prinus*) has been studied, and the cause was found to be a parasitic fungus (*Sphaeropsis malorum*). There has been no opportunity to undertake any control measures. A brief abstract has been published (Phytopath. **4**:44–45, 1914; Tree Talk **2**:13–15, 1914).

Apple-tree diseases.— Important discoveries have been made in regard to the life history of the fungus causing the most serious canker on apple trees in New York, and these discoveries have been published (Phytopath. **3**:290–295, 1913).

The European canker caused by *Nectria ditissima* has also been studied.

The records of various surgical treatments and methods of dressing wounds have accumulated until it is now possible to draw conclusions. These data will be tabulated and made available for publication.

Gladiolus disease.— Extensive work on the relative thermal death point of the host and the parasite has developed the fact that there is no possibility of controlling this disease by thermal treatments at digging time.

Experiments are now under way to determine the relative value of various green manures in freeing the soil from the disease-producing organisms.

Fungicidal value of sulfate of iron.— Work has been continued in spraying raspberries for anthracnose, and a method of materially reducing the ravages of this disease has been found. The causal organism has been studied, and knowledge of its life history materially increased. The use of sulfate of iron as a neutralizer of lime-sulfur solution to prevent burning proved detrimental in the apple work mentioned in the last report. In the past season the combination has been used in spraying for yellow leaf of cherries.

Control of oat smut.— Tests have been made of various methods of treating seed oats to prevent the smut disease. It appears that a method has been devised that will materially reduce the time involved in the treatment, but the method should be tested for another season before it can be recommended. The investigation has been extended to cover similar treatments for stinking smut of wheat, a disease which has suddenly become of great commercial importance in the State.

Fusarial flora of the potato.— This study has proved very much more extensive than was anticipated at the outset. Over fifty distinct species and varieties of the genus Fusarium have been found to inhabit the potato. The group is a very difficult one to study, and the classification and describing of this number of plants has required a large amount of time. The systematic features of the work are completed and ready to publish, but the pathological phases remain to be worked out.

Timothy smut.— The work on this important disease is well under way. Practically nothing is recorded of the life history of the organism causing the disease, and nothing regarding the pathological features. Data on these subjects are being accumulated as rapidly as possible, and it is hoped that they may furnish a basis on which to establish satisfactory control measures.

Champlain Valley apple-disease investigations.— The diseases receiving particular attention are physiological in nature. Root injury from freezing has been studied, and some interesting observations on the influence of scions on their stocks have been recorded. Two unnamed troubles have been studied extensively. One, locally known as "cork," seems to be somewhat of the same nature as Stippen, but is more injurious to the fruit; the other, spoken of as "the Stevens disease" (because it was first observed in the orchard of Mr. Stevens), is recognized by a degeneration of the hypodermal parenchyma of eight- or ten-weeks-old fruits and their dropping from the trees.

Hop diseases.—This work has been inaugurated recently. Some reciprocal crosses have been made between the common cluster hop

and a native red vine which does not have mildew, in order to develop, if possible, a desirable hop which possesses resistance to this disease. Some root troubles have also come in for investigation.

Peony diseases.— The work on the Botrytis blight of peonies has been continued by Professor Whetzel while on sabbatical leave in Europe. Most of the original material in the herbaria of Europe has been seen and examined. The disease has been studied as it occurs under natural conditions in Holland, Sweden, and Germany. In this connection a monographic study of the genus Botrytis has been undertaken, and much has been accomplished by Professor Whetzel while working in the laboratories of Doctor Klebs at Heidelberg.

Mycological researches.— Attention has been given chiefly to a complete morphological and cytological study of an interesting and rare plant, *Eocronartium typhuloides*. An undescribed species of Crepidotus parasitic on mushrooms has been found and studied. A description of the fungus is ready for publication.

Environment studies.— Under this caption the problem of the relation of health of plants to susceptibility to various pathogens is being studied. The health of the plant is being altered by changing various environmental conditions, and inoculations are then made with various pathogens. The work must be continued for a long period of time before results permitting of generalizations may be secured.

EXTENSION

The extension work of the Department includes teaching at extension schools, demonstrations, cooperative spraying experiments, exhibits, lectures, trips of inspection, and correspondence. In all, 186 places, representing 126 localities in 30 counties, have been visited during the past year. Thirty-four of these visits have been made at the request of and in cooperation with farm managers.

Teaching at extension schools.— Lessons in plant diseases were given in extension schools at the following places: Ellington (Chautauqua County), Sherwood (Cayuga County), Hannibal (Oswego County), Greigsville (Livingston County), Holley (Orleans County), Meridian (Cayuga County), and Monticello (Sullivan County). The aim of these lessons has been to give the farmers an idea of the nature and cause of plant disease so that control measures may be more intelligently applied. Actual practice periods were given in which specimens of diseased plants were studied and fungicides prepared.

Demonstrations.— Seventeen meetings were held in various parts of the State in order to demonstrate cutting out fire blight of pears, spraying and dusting apples, and treatment of oat and wheat seed to prevent

mut. Seven of these were at the request of farm bureau managers. In ooperation with the Farm Bureau Manager of Monroe County, potato praying demonstration experiments have been carried on with seven-een farmers of Monroe County.

As in previous years, the men associated with field laboratories have .ccomplished a large amount of extension work in connection with their ivestigations. In some cases the extensive phase of the work is equal in nportance to the investigative phase.

Exhibits.— Exhibits of the common diseases of orchard crops and of nethods of control were made at the annual meetings of the Western New 'ork Horticultural Society and the New York State Fruit Growers' Asso-iation. Exhibits of the diseases of farm crops were made at the county airs of Washington, Yates, Erie, and Montgomery Counties, and at the State Fair at Syracuse. A special feature was made of the method of treat-ng oat and wheat seed in order to prevent smut, and of preparing bordeaux nixture. An extensive exhibit of plant diseases was made for Farmers' Veek visitors at the College of Agriculture.

Lectures and field meetings.— Fifty lectures on some phase of plant disease vork have been given by members of the staff at farmers' institutes, at neetings of horticultural societies, before granges and farmers' clubs, and at ther occasions where farmers have gathered. In addition to these there ave been held, in connection with a trip with a "Potato Special" car over he New York Central Railroad Company's lines, twenty-three lectures in he coach and thirty-five talks in potato fields where farmers have met.

Trips of inspection.— An inspection of potato tubers in eastern Long sland was made in order to ascertain whether powdery scab existed. It vas found on a few tubers obtained the preceding autumn from Maine for lanting purposes. Nearly all the tubers obtained from this source had een planted before the inspection was made. In cooperation with the Federal Horticultural Board and with the assistance of farm bureau mana-gers, an inspection was made of potato tubers at a few places in the three northern counties of New York. A few tubers were found slightly affected vith powdery scab. A tour of inspection of a few of the potato sections of Clinton, Franklin, Monroe, and Ontario Counties was made by two mem-bers of the staff in company with plant pathologists from the United States Department of Agriculture at Washington, from several state experiment stations, and from Germany. Trips of inspection with farm bureau man-agers have been made in Chautauqua, Erie, Niagara, Wyoming, Monroe, and Dutchess Counties. In a few cases visits have been made to farms of individuals who requested them and who have paid the traveling expenses connected with the trip.

Correspondence.— During the year 3245 letters were written, mostly in

answer to inquiries regarding the control of plant diseases. Also several thousand circular letters and cards were sent out, giving notice to growers of the method of plant disease control and of the proper time to apply control measures.

RECOMMENDATIONS

The most urgent need of the Department, as in the past, is for more satisfactory quarters. At the end of the year the entire Department was moved to the basement of Bailey Hall. The actual floor space is ample for the present needs of the Department, but the poor natural lighting reduces the available area at least one third. With the base of the small-paned windows five feet from the floor, the light will never be satisfactory for close microscopic work.

The intense congestion of former years in the undergraduate courses has been relieved, and it is now possible to accept all the regular students who seek instruction in the Department. The graduate laboratories and offices for members of the staff, however, are still very much crowded. Increased floor space and better facilities for properly handling the increasing number of graduate students are among the imperative needs of the Department at the present time.

An elementary course in general plant pathology for special students is being urged more and more strongly by those special students who have had botany or biology in the high school and who have not time to carry the botany and biology regarded as essential prerequisites of our present collegiate course in the subject. This demand is a legitimate one; it can be met only by the appointment of an additional instructor in the teaching division and by providing additional floor space for the work.

There is increased need for cold-storage facilities for experimental work. A series of chambers that may be held at constant low temperatures would assist materially, and such facilities are absolutely necessary for the forwarding of a number of important lines of investigation.

The disease garden is now filled with trees and smaller plants of various kinds, and practically all of the present area is taken up with long-time experiments. The space between the rows of trees has been used for work with annuals, but the trees now make so much shade that the land can be used only for trees and for a limited number of shade-enduring plants. More land is needed for a disease garden, not only for experimental work by members of the staff but also as a place where suitable material can be developed for teaching purposes.

It is impossible to make a trip into the country at any time during the growing season without being confronted constantly with plant disease problems, many of which are entirely new, or about which so little is known that no satisfactory information can be given. Considering the fact that

each individual crop may be subject to one to twenty specific diseases, and considering the great diversity of crops grown in the State, it is evident that no one person can know much about the many diseases of our various crops, and that in order to do effective work there should be at least one man devoting his time exclusively to the study of the diseases of each of the important crops.

Much of the work reported above is in part financed privately or is the work of graduate students whose productive period in the Department is usually of relatively short duration. The extent of private aid is such that if the funds are discontinued the work must drop. Such cooperations are extremely valuable for solving certain specific problems, but have no value in maintaining the many long-term pieces of investigation that are confronting us. It would seem that these problems can be met only by securing funds which shall be devoted specifically to research.

DONALD REDDICK,
Professor of Plant Pathology, and Acting Head of Department 1913-1914.

DEPARTMENT OF SOIL TECHNOLOGY

TEACHING

The number of undergraduates registered in this Department for the year ending September 30, 1914, was 677. The registration for the previous year was 445. This increase was due, in part, to the fact that instruction was offered for the first time to the winter-course students. Subtracting the winter-course registration of 196 from the total, we still had a registration of 481, an increase of 36 over that of the previous year.

Nineteen graduate students were registered for major and minor subjects in the Department.

In order to avoid unnecessary duplication of work of other departments, it has been deemed advisable to discontinue Course 7, Manures and Fertilizers. Part of the work formerly given in this course will be incorporated into Course 1, Principles of Soil Management.

INVESTIGATION

Investigations under the Adams fund

There has been no change in the number or in the subjects investigated under the Adams fund during the past year, although naturally there has been a change in the phases of the subjects under investigation, as progress has been made. The three divisions into which this work has been differentiated are the following:

1. *A study of the composition and concentration of water-soluble material of soils under different methods of soil treatment.*—The experiments were begun with a study of the nitrate content of a soil under several different crops. This showed characteristic relationships to exist between certain of the higher plants and the formation of nitrates in the soil, also between the formation of nitrates and the stage of development of the plants. Certain higher plants, notably maize, apparently stimulate the formation of nitrates during the earlier stages of growth, while all the plants used in the experiment appear to depress nitrification as they approach maturation. For instance, the nitrates in soil on which maize grows are often higher than on contiguous unplanted soil, even when fifty per cent of the nitrogen of the crop has already been taken from the soil. At the close of the growing period, nitrates are naturally greatly reduced under all crops, but to an extent not accounted for by the nitrogen removed in the crop.

Assuming that these hypotheses are correct, the Department is now endeavoring to ascertain through what agency the plant influences the activity of the nitrogen-transforming bacteria. The possible secretion of oxidizing and reducing enzymes by the plant roots is being investigated,

also the possibility of the influence of changes in the composition of the soil solution through the removal of certain ions by absorption at one stage of growth and the liberation of ions at another stage. The quantitative relation of certain ions in solution appears to be a factor in determining the growth of certain nitrogen-transforming bacteria as well as of higher plants.

The effect of the proportion of carbon dioxide and of oxygen in the soil air is also being investigated, but, in the range through which they may be expected to vary in soil air, they have not been found to greatly influence the formation of nitrates. Whatever the depressing influence may be, there is no doubt that it is quickly destroyed by aeration, but unless the soil is aerated or frozen it persists for some time. Almost any condition of soil, however, whether of an organic or an inorganic nature, is profoundly affected by aeration of the particles.

In the course of this investigation the influence of various conditions on the formation of nitrates has been studied, and the quantities of some other soil-water solutes have also been determined.

2. *Influence of soil moisture on the availability and utilization of plant nutrients in soils.*— The quantity of moisture that a soil contains has been generally conceded to be the most potent factor in determining crop yield. It is not known, however, to what extent the influence it exerts is directly on the crop, and to what extent it operates by making more or less soluble the plant nutrients in the soil.

Changes in moisture content affect the activity of the bacterial flora and also the coagulation and formation of colloidal matter, both of which are agents concerned in the supply of water-soluble matter. Experiments have been conducted mainly in earthenware pots in the greenhouse, the soil being maintained for periods of two years at certain definite moisture contents, or else changed at certain shorter periods in order to obtain the effect of known changes in moisture content. All work was done synchronously on soils kept bare of vegetation and on soils at the same moisture contents on which plants were grown. The utilization of the nutrients was thus compared with their solubility at the end of the period, as measured by the water-soluble and the $\frac{N}{5}$-nitric-acid-soluble constituents.

While nitrogen transformations were greatly influenced by the moisture contents of the soil, the solubility of mineral nutrients was apparently not affected by moisture contents extending over periods varying from several weeks to several years. Experiments are now in progress in which the soil is subjected to more rapid changes in moisture content. This, however, is different in principle; it is a determination of the effect of change in moisture content rather than the effect of a sustained moisture content. A study of the variation in moisture content on the colloidal matter as measured by the absorption of dyes and of hygroscopic moisture will also be attempted.

3. *Investigation of the condition under which lime is removed from soils, and of the changes that accompany it.*— The experiments are conducted in large concrete tanks on Caldwell field. The first series of these tanks was filled with soil in 1909. The last set was filled in 1913, and these tanks are still being tested before placing them in experiment. Each tank is four feet two inches square (.0004 acre), with a maximum depth of four feet six inches and a minimum depth of four feet. The capacity of a tank is about three and one half tons of soil. There are twenty-four tanks, placed in two rows of twelve tanks each. Between the rows of tanks is a tunnel, and from the bottom of each tank a tube for carrying off the drainage water runs into the tunnel. The drainage water is collected in galvanized iron cylinders, which are also measures, and the volume of the water and its composition are determined.

In the process of filling, the funnel-shaped bottom of each tank was filled with sand. The soil from the fourth foot in depth, as soil lay in the field, was then placed in a corresponding position in the tank, then the third foot, the second foot, and finally the surface foot, so that the soil layers were in their natural positions. The volume of soil is large enough to pack firmly after it has stood for some months, and the temperature and moisture content are similar to those of the surrounding soil. It is quite probable that the biological and chemical processes of the soil in these tanks are analagous to those that occur under field conditions.

A record is kept of the composition of each horizontal foot of soil in the tanks, and of the material applied to the soil and removed in the crops. Some of the tanks are kept continually without vegetation, but fertilizers or other amendments are applied to them as to the others. The effect of certain crops on the loss of calcium and other bases is being studied, and also the effect of potassium in the form of a sulfate. This is being conducted on Dunkirk clay loam, with which twelve tanks are filled. The other twelve, which contain Volusia silt loam, will be treated differently.

The most striking fact brought out by the experiments up to the present time is the protective action of plants in conserving calcium, and, to a less extent, other bases, as well as nitrogen. The loss of nitrogen in uncropped soils had been shown by Dehérain in the tanks at Grignon, but he had confined his chemical control to nitrogen and had not discovered the protective action of plants for calcium.

A series of plats on soil similar to that in the first twelve tanks are treated in a manner to duplicate the experiments in the tanks. This is done for the purpose of ascertaining whether the changes in the soil through a series of years correspond under the conditions of the field and the tanks. In the tanks no upward movement of soil water is possible below a depth of four feet. In the field there may be such a movement brought about by the

capillary rise of water in the soil, or by other agents. These field plats are maintained as a check on the tank experiments.

Other investigations

1. *Nitrogen balance under timothy and under alfalfa* — In the course of the experiments with nitrates under different crops, it was found that soil from under alfalfa nitrified more rapidly than did soil from under timothy. In order to ascertain whether this was due to the greater quantity of nitrogen in the legume soil, the plats were sampled and nitrogen was determined in the soil. There was no essential difference in the nitrogen content of the soil under the two crops. This raised the question whether there had been any greater accumulation of nitrogen under the legume than under the grass. The crops had been on the land for six years, and no analyses of the soil before planting were available, hence no definite conclusion could be drawn. As legumes may use combined nitrogen, it seems possible that under some conditions the nitrogen balance under alfalfa may be no greater at the end of several years than under timothy. If this be true, the better growth of most crops following the legume may be due to the readier availability of the soil nitrogen after that crop, or possibly to some other cause, rather than to the higher nitrogen content of the soil as has generally been supposed.

An experiment designed to measure the accumulation of nitrogen under alfalfa and timothy on rich and medium soil both limed and unlimed was begun in 1913. Analyses of the soil of seventy-eight plats was made at the beginning of the experiment and will be repeated at the end of five years.

2. *Examination of the chemical composition and of certain physical properties of some important types of soil.*— Representative samples of certain types of soil are taken from three different parts of the State. Ultimate analyses are being made of these samples in order to ascertain whether the composition of a soil type, as now classified, is fairly uniform and sufficiently characteristic to distinguish any type from other types. This is part of a study of soil survey methods now in use in this State. No results have been published. It will be continued as rapidly as funds permit.

3. *Test of the uniformity of fertilizer needs for a soil type.*—This is another phase of the study of soil survey methods. Soil from two distinct areas of a soil type are brought to the Station and placed in cylinders sunk in the ground. These cylinders are three feet deep and eighteen inches in diameter. The soil to be treated is removed to a depth of three feet, keeping each foot separate, and placed in the cylinders in the order in which it occurred in the field. Fourteen cylinders are filled with the soil from each locality, or twenty-eight cylinders with each type. These are to be treated with certain combinations of fertilizers containing nitrogen,

phosphorus, and potassium, and also lime. It is desired to ascertain whether our present soil types are an index to the fertilizer needs of a soil. The test will require some years for its prosecution.

4. *Use of fertilizer on timothy.*— In recognition of the importance of the growth of timothy, in respect to which New York exceeds all the other States, a number of experiments with timothy alone and with timothy and clover are under way. A series of plats with timothy in rotation with corn, oats, and wheat have been under experiment for nine years. These serve as a good illustration of the benefit that timothy may derive from top-dressing it with commercial fertilizers or with farm manure. Yields of four tons per acre have been secured by this means on land that without such treatment gave only one and one fourth ton. The net gain per acre from use of commercial fertilizers in their most profitable combination amounted to $65 for the six-years rotation, and the most profitable quantity of farm manure gave a net return of $78. The hay crops only were fertilized, and the plats giving the largest yields of timothy produced the best grain crops.

Experiments now in progress are designed to show to what extent clover grown with timothy can take the place of nitrogen in the fertilizer, also whether it is more profitable in a rotation to fertilize only the hay crops or only the grain crops, or to fertilize both.

The experiments have also illustrated the fact that mineral fertilizers may be made to contribute large quantities of organic matter to the soil through the larger quantity of sod that is formed on the timothy land to which they are applied. As farm manure is a product that will probably not increase much in output, the problem of securing organic matter for the soil is an important one.

5. *Tests of acid phosphate and raw rock phosphate.*— This is a test of the effect of acid phosphate and raw rock phosphate on the yields of certain crops, when these fertilizers are used with fairly heavy applications of farm manure and when they are used with only mineral fertilizers, as, for example, nitrate of soda and muriate of potash. It is particularly desired to ascertain whether the incorporation of farm manure under these conditions increases the effectiveness of the raw phosphate.

A six-years rotation is in progress, of which the courses are corn, oats, wheat, each one year, and hay three years. Plats receiving the raw phosphate have a three-years supply applied before seeding to grass. The grain crops receive this fertilizer annually, and all crops receive acid phosphate annually. Farm manure is applied to the grass and the corn at the rate of fifteen tons per acre.

6. *Experiments with different forms of lime.*— Lime may be purchased in the form of burned lime or in the form of limestone which, instead of being burned, is ground to a powder. The relative cost of these forms of lime

varies in different localities, but it is desirable to know something of their relative efficiency in providing the soil with the basic material for which the lime is valuable. Another consideration is the degree of fineness of the ground limestone. Obviously, the smaller the particles, the greater is the surface exposed to the solvent liquids in the soil. Burned lime does not need to be ground, but it slakes when it is added to the soil. Three sizes of limestone particles are used in the experiment. The size is determined by the sieve that the particles will pass through, the sieves having respectively ten, fifty, and two hundred meshes to the inch.

In addition to the forms of lime already mentioned, gypsum, marl, dolomite, magnesite, and Solvay lime are being tested. The last-named is a mixture of oxide and hydrate. Ground limestone is also being used in different quantities per acre, as is also caustic lime. Applications of these substances have been made only once, except on the plats that are receiving burned lime biennially.

Sorghum, oats, and wheat have been raised on the plats treated with these various forms of lime. No legumes and no sod crops are being used, as they might introduce secondary effects occasioned by the manurial value of the residue remaining from the crop. The organic matter in the soil is maintained by the use of farm manure.

The chief differences brought out by the experiment so far are the better yields on the plats treated with caustic lime than on those treated with ground limestone, and the depression of plant growth on the plats receiving magnesite. As this is a heavy clay soil, the burned lime might be expected to have an ameliorating effect on the structure.

7. *Continuous cropping without manures.*—This is an experiment designed to ascertain the effect on the productivity of this soil when it is cropped continuously without replacing any of the mineral nutrients removed in the crops. It is intended, however, to maintain a liberal quantity of organic matter in the soil by means of grass or legumes. Thus a series of five plats will each year have three of the plats in timothy, one plat in corn, and one in oats seeded with timothy. The next year the corn plat will be seeded and one of the timothy plats will be planted to corn. In this way each plat will be in timothy three years, corn one year, and oats and timothy seeding one year. In another series the seeded crop is alfalfa, and in another series it is timothy and clover. Each series is duplicated.

The feature in which this experiment differs from continuous cropping experiments generally conducted, is in the attempt at the maintenance of the supply of organic matter without the addition of any mineral nutrients. An incidental result of the experiment will be to compare the manurial value of timothy, alfalfa, and timothy and clover sod. It will, of course, be many years before the data begin to contribute to the main object of the experiment.

8. *The value of nitrate of soda applied to timothy on this soil.*—This has been well demonstrated. It is now intended to test two other high-grade carriers of nitrogen in comparison with nitrate of soda in a rotation, but particularly on timothy hay. The fertilizers being tested are ammonium sulfate and calcium cyanamide. The latter is of recent invention, but it is now being extensively manufactured in Europe and to some extent in this country. In its manufacture atmospheric nitrogen is the source of supply. As commercial fertilizers heretofore made use only of the combined nitrogen provided by nature, the supply of which must ultimately become exhausted, the production of a fertilizer made by fixing atmospheric nitrogen is a matter of great importance.

Ammonium sulfate has a constantly increasing output, as it is a by-product in the manufacture of illuminating gas and in the production of coke, and, while formerly wasted, is now being saved by a constantly increasing number of producers of gas and coke.

These two fertilizers are being tested singly and in combination with sodium nitrate. As is customary when a single fertilizer ingredient is to be tested, the other ingredients are used in excessive quantities. No definite results have yet been obtained.

9. *Local fertilizer tests.*— Tests of different kinds and quantities of fertilizers applied to a rotation of crops with and without the application of lime are being conducted for the purpose of ascertaining the fertilizer needs of the particular soil under experiment. The work is in cooperation with persons at the two points at which the tests are made.

EXTENSION

There have been no important changes in the work of the extension section during the past year. The staff was increased by the appointment of W. W. Warsaw, a graduate of the Iowa State College, who assumed his duties on the first of February. On July 1, C. C. Engle resigned as an assistant.

Soil survey

Within the year, soil survey work has been in progress in Oneida, Chautauqua, and Clinton Counties.

1. *Oneida County.*— The field work of this area was completed in November, and the work on 180 square miles of the total of 1190 in the county would fall within the succeeding fiscal year. The field work was in charge of E. T. Maxon for the United States Bureau of Soils and E. H. Stevens for this College. The report and map are now ready to go to press.

2. *Chautauqua County.*— Within the present fiscal year, 562 square miles of the total of 1062 in the area have been traversed. The work was in

charge of T. M. Morrison for the United States Bureau of Soils, and during the first part of the year C. C. Engle, and the latter part Glen L. Fuller, for this College. This season's work was chiefly on the Lake Erie plain and forelands in the Grape Belt on the northern side of the county. The soil conditions are somewhat complicated by the union of rather strong recessional morainic features on the hills with the lake deposits of the forelands. The glacial lake soils on the plain will probably be put in a separate series from the Dunkirk, with which they have been correlated in the past, due to their markedly gray and chrome yellow color, which appears to be derived from the associated shale formations.

3. *Clinton County.*— The survey of Clinton County, which lies in the extreme northeastern part of the State, was begun in the middle of June by Earl T. Maxon for the United States Bureau of Soils and W. R. Cone for this College. The county contains 1050 square miles, and the field work was practically completed by September 15. This rapid progress was made possible by the large extent of rough, mountainous country, which required very little detailed attention. The county was taken up for survey, first because of the strong request from the farm bureau and the agricultural interests of the county, and, second, because it represents a section of the State in which survey work had not been done and therefore gives us the cue to the soil correlations in that region. Four primary series constitute the area. The bulk of the upland is a very sandy and stony glacial till, derived primarily from the Potsdam sandstone. This series is called the Coloma. It is extensively identified with the production of potatoes, especially at the higher elevations, and this crop relation is probably due to climatic factors as much as to soil conditions. The types in this series have a fairly high agricultural value.

The map and report of Orange County were completed in the last fiscal year, and were published in September of this year by the United States Bureau of Soils. An edition of three thousand copies of the Orange County survey will be issued as Bulletin 351 of this Station. It is expected that subsequent surveys will be published in the same manner.

In addition to the regular survey work, two special reconnaissance surveys have been made within the year. One was of three days duration over the Kingston branch of the New York, Ontario, and Western Railroad from Port Jervis to Kingston, taking in the interior valleys along which that railroad is situated. This was for the special convenience of the railroad mentioned. The other was a survey of the township of Gouverneur, in St. Lawrence County, in connection with a brief general agricultural and social survey of that township undertaken by the Chamber of Commerce of Gouverneur. In neither case was a map prepared, but the soil conditions and their primary agricultural relations were pointed out in a brief letter report.

Work on the chemical survey of the soils of the State was continued in the analyses of samples from Tompkins County.

Irrigation

Demonstration of the value of irrigation under conditions of the locality was continued on the Baker farm, north of Rochester. At the beginning of the season, the cooperation of the Rochester Railway and Light Company was largely withdrawn by the transfer of Mr. Fisher, agriculturist of that company, who had assumed responsibility for the details of the work. This was considered to be necessary due to financial retrenchment which the company felt obliged to make, but the company finally continued the equipment for the joint use of the Baker farm and the College. Conditions were not favorable for the application of water to fruit crops this season, and the equipment was in a trial of irrigation of the tomato crop; and, while the returns are not yet completely in, it is safe to say that a marked benefit has been observed.

Drainage

The appointment of Mr. Warsaw has made possible the more active prosecution of drainage work. He began his duties on February 1, as indicated above, and took up work in the field on March 20. Since that time thirty-four farms have been visited. Surveys have been made for twenty-eight of these, and complete systems were laid out on twelve. To this number should be added three farms for which surveys were made by other members of the staff before the beginning of Mr. Warsaw's appointment. The aggregate area of the farms involved was 4900 acres, and of this area 2000 had a marked need for drainage. Approximately three hundred miles of drainage system have been suggested or laid out. In this work the representative of the Department is equipped with a transit for making survey where necessary. It is found that, as a rule, no extensive survey is necessary. A relatively small number of sites is sufficient to show the lay of the ground and afford the basis for suggestion as to the best method for drainage. No large projects have been undertaken.

The Department has been called into conference in the preliminary investigations of two large swamp areas where the question concerned is primarily the agricultural value of the area. One of these is the Newpaltz area in Ulster County, with which we have been in touch for two or three seasons. The other is the Pope Mills swamp in St. Lawrence County, involving about 2000 acres of muck land, the drainage of which the State Conservation Commission has been considering.

The Department was called to the assistance of the Department of Rural Engineering in the extension and completion of a drainage system near Derby, in Erie County.

The aid of the Department was sought by a group of progressive farmers in Chemung County, in order to present their drainage situation to the Erie Railroad, the embankment of whose lines has resulted in the obstruction of the drainage on these farms. The outcome of this matter is not yet determined, but a conference has been arranged between the proper representatives of the two groups concerned.

The educational value of drainage work has been extended by holding three field meetings. The first of these occurred on the farm of N. R. Peet, at Webster, in Monroe County, on May 23. Arrangements were made with the Buckeye Traction Ditcher Company, the Jeschke Manufacturing Company, the manufacturers of several small plows for the demonstration of their machines, and the DuPont Powder Company for the use of dynamite in opening up ditches. Samples of tile, smaller drainage tools, and a number of small levels and transits, were on exhibition, and systems of drains were laid out for the area and were explained by means of lectures and blueprints. The attendance was approximately six hundred persons. This demonstration was carried out in cooperation with the Monroe County Farm Bureau.

The second meeting was held in cooperation with the St. Lawrence County Farm Bureau, at Gouverneur, on August 24 and 25. The use of several types of machine was demonstrated under very favorable conditions. Lectures were arranged at intervals, and approximately one hundred and fifty persons were in attendance.

The third meeting was at Adams, on September 8 and 9, in cooperation with the Jefferson County Farm Bureau, and was conducted in practically the same manner as the meeting at Gouverneur. About one hundred and twenty-five persons were in attendance.

In the latter part of August, the second volume of Proceedings of the New York State Drainage Association was printed and distributed. This publication of one hundred and thirty-eight pages has been edited, and funds for its printing raised, by members of this staff. It covers the proceedings of the association for the years 1912 and 1913, and presents in a preliminary form a large amount of practical experience on drainage and soil improvement.

Extension schools

Members of this staff took part in twelve extension schools during the year, with an aggregate of forty-eight days of actual instruction, or an average of four days per school. Three of these schools were one-day stands of an experimental nature, one department presenting a full day's program. The usual course of lectures occupies one full week and includes eight lectures with some demonstration material. The call

for instruction in soils in these schools continues to be much larger than the staff of the Department is able to meet, and it is gratifying to receive a heavy call for return engagements. It has not been the policy, however, to grant these except in special cases, in the belief that larger benefit will result from work in new fields.

Farm train

The Department took part in the farm train on the Ontario and Western Railroad, which continued for two weeks, March 16 to 28. Twenty-three regular stops were made. The total attendance at these stops was about four thousand persons.

Exhibits

An educational exhibit was made at the State Fair and at one local fair. This season the Department prepared an exhibit for the Extension Department, which was combined with the exhibits from other departments and put in the charge of a representative of the Extension Department in order to give a better-balanced exhibit to the local fairs at a smaller cost.

Visits to farms

Fifteen farms were visited at the request of the owners, for the purpose of giving assistance in their improvement and management.

There is a continual call for miscellaneous lectures before a variety of audiences. During the past year twenty-nine lectures were given before Farmers' Week audiences and at other institutions — farmers' institutes, chambers of commerce, farm bureau meetings, granges, and church organizations.

Correspondence

The correspondence of the office continues to grow. During the past year 3335 regular letters have been sent out, to which should be added 1335 circular letters.

PUBLICATIONS

T. Lyttleton Lyon and James A. Bizzell. Some relations of certain higher plants to the formation of nitrates in soils. Cornell Univ. Agr. Exp. Sta. Memoir No. 1.

T. Lyttleton Lyon and James A. Bizzell. A discussion of certain methods used in the study of "the associative growth of legumes and non-legumes." Journ. Amer. Soc. Agron. Vol. 5 (1913), p. 65.

T. Lyttleton Lyon, James A. Bizzell, and Joel Conn. An examination of some more productive and some less productive sections of a field. Cornell Univ. Agr. Exp. Sta. Bul. 338.

T. Lyttleton Lyon and James A. Bizzell. Experiments concerning the top-dressing of timothy and alfalfa. Cornell Univ. Agr. Exp. Sta. Bul. 339.

James A. Bizzell and T. Lyttleton Lyon. Estimation of the lime requirements of soils. Journ. Indus. Eng. Chem. Vol. 5. No. 12, p. 1011.

T. Lyttleton Lyon. Report of the meeting of the international commission for the mechanical and physical examination of soils, held at Berlin, October 31, 1913. Journ. Amer. Soc. Agron. Vol. 6 (1914), p. 94.

T. Lyttleton Lyon. Soil experiments on Caldwell field. Cornell Countryman. Vol. 11 (October, 1913), p. 4.

James A. Bizzell. New nitrogen fertilizers. Western New York Hort. Soc. Ann. proc. **59**: 105.

Harry O. Buckman. Fertilizing the rotation. Journ. Amer. Soc. Agron. Vol. 5 (1913), p. 157.

Elmer O. Fippin. Nature, effects, and maintenance of humus in the soil. Cornell Reading-Course Lesson for the Farm. Vol. 3, No. 50, Soil Series 3.

Elmer O. Fippin. Soil moisture and crop production. Cornell Reading-Course Lesson for the Farm. Vol. 3, No. 70, Soil Series 4.

Elmer O. Fippin. Outline of the function and use of commercial fertilizers. Cornell Univ. Agr. Exp. Sta. Circ. No. 23.

Elmer O. Fippin. Outline of the relation of the use of lime to the improvement of the soil. Cornell Univ. Agr. Exp. Sta. Circ. No. 25.

Elmer O. Fippin. Soil problems of the florist. American Florist. Vol. 43, No. 1372, p. 1457.

RECOMMENDATIONS

It is desirable that there shall be a sufficient number of assistants in the Department to make it possible to hold recitations in the introductory course in soils. Such a system would add greatly to the disciplinary value of the course. It would necessitate increasing the number of assistants to five for two terms each.

Plans for the development of the ranges of glasshouses involve the removal of the old house now used by this Department. As this house is a very essential part of the laboratory equipment of the Department, it is recommended that provision be made for building another house before the old one is removed.

An increase in the number of tanks for soil investigation would help materially in the prosecution of the experiments now under way.

It is desirable that an expert in soil survey, who will be a permanent employee, be engaged, in order to give continuity to the work. At

present this work is done entirely by students who seldom serve for two consecutive summers. A man engaged permanently would thus be available also for extension work in winter.

T. LYTTLETON LYON,
Professor of Soil Technology.

DEPARTMENT OF POMOLOGY

TEACHING

The instruction in pomology is planned to meet the ultimate needs of the students, and to that end the courses provide training for practical work, for teaching, and for research.

Hitherto no differentiation in courses had been made for regular and special students. Beginning with the year 1913–1914, courses were offered for special students only, and all special students in the College desiring instruction in pomology were urged to enter these courses.

The Department offered regular courses in the 1914 summer school. and the attendance in these courses was large, as the figures below will show.

Courses in fruit-growing were offered to the winter-course students for the first time during the year 1913–1914. The courses were designed primarily for farm boys who desired to make fruit-growing a specialty. In addition to the practical courses in fruit-growing, the work included a study of plant diseases, injurious insects, fertilizers, and soils.

The number of students registered in pomological courses during the year 1913–1914 was as follows:

Course	Subject	Number of students registered				
		First term	Second term	Third term	Winter course	Summer school
1.	Elementary Pomology	198	...	16	...	...
1a.	Elementary Pomology (laboratory)	...	157	10	...	...
2.	Practical Pomology	...	154		...	...
4.	Bush Fruits	...	101		...	...
5	Nuciculture	31	...	...	...	...
6	Spraying of Fruit Trees		42	...	...	...
8	Varieties and Judging	56	...	...	...	...
10	Systematic Pomology	...	14		...	...
16.	Elementary and Practical Pomology (special students)	21	...	...	...	...
17.	Spraying of Fruit Trees (special students)	...	26	...	...	...
19.	Research in Pomology	29	13	6	...	...
20	Seminar	...	17	...	...	...
	Graduates taking major	3	1	1	...	...
	Graduates taking minor	5	4	1	...	...
Winter course						
1.	Commercial Fruit Growing	...	...	...	59	...
2.	General Fruit Growing	...	...	...	133	...

Course	Subject	Number of students registered				
		First term	Second term	Third term	Winter course	Summer school
Summer school						
A	General Fruit Growing	...	...	.	....	28
B	Small Fruits	...	....	...	....	34
C	Advanced Pomology	.	...	.	...	9
		343	529	34	192	71

Total registration for 1913–1914, 1169.

INVESTIGATION

Considerable attention has been given to the care and planting of new orchards. About fifty acres of land of the university farm has been set aside for pomological work. The planting is now nearly completed. In connection with the planting of these orchards, the list of experiments mentioned below were continued during the summer. These experiments will require several years for completion.

Variety tests.— A collection of varieties of each fruit is being made. The purpose of this collection is twofold: first, to study commercial varieties with respect to hardiness, productivity, variability, and quality; second, to study new varieties with respect to adaptability to conditions in New York.

The value of selected scions.— In the case of a few varieties of apples, scions have been selected from bearing trees which are known to be productive and the fruit of which is excellent as to type. Tentative arrangements have been made with the Department of Plant Breeding to cooperate in making a thorough study of this subject with the strawberry and the apple.

Irrigation in New York as it affects the peach.— In cooperation with the Department of Rural Engineering and with W. E. Bargar, of Lockport, New York, an experiment was started in the spring of 1912 in order to determine the results of irrigating a peach orchard. Mr. Bargar furnished the peach orchard and the money for the irrigating plant, which when installed had a capacity of four hundred gallons per minute. Water has been applied at regular intervals during the summers of 1912 and 1913 and the results are computed for the summer of 1912. There being no crop, the trees were not irrigated during 1914, but plans are made to irrigate during the season of 1915 if there is a crop.

Pruning.— Practically all the commercial varieties of apple, pear, peach, plum, cherry, and quince have been placed under a pruning experiment. Under this experiment, records are being kept along the following lines: effect of the different styles of shaping on yield, size, and color of fruit; effect of shaping on the water supply for the tree and on the "June drop"; effect of incipient drying of leaves and fruit of the apple; effect of the various shapes on resistance to water movement; effect of summer pruning as compared with pruning during the dormant season; the best method of forcing water sprouts into fruiting by pruning in summer and during the dormant season; and the possible effect of stimulants in forcing water sprouts where they are desired.

An orchard of eight acres at Port Byron, New York, has been leased for a pruning experiment. With the old trees, a study is being made as to the best methods of renovating old orchards where the trees have been left too close; in a part of the orchard half of the trees are removed, and in another part all the trees are left but are pruned back rather severely.

Tree planting.— Under this heading, a study is being made of the effect of the benefits to be derived from blasting the holes for planting. In an orchard planted in the fall of 1913, some of the holes in which apple, peach, and cherry trees were planted were made by the use of dynamite. A study is being made of the effect of the common practice of storing trees through the winter and their behavior at transplanting, and the possible effect of various stimulants in overcoming the ill effect of storage. A thorough study of the root growth of trees is also being made, with especial reference to the season in which greatest root growth occurs.

Hardiness studies.—The climate at Ithaca should be ideal for determining the relative hardiness of different varieties of the peach, since a large percentage of the winters may be cold enough to kill buds and perhaps other tissues of the trees. A large number of varieties have been planted with a view of determining more carefully their relative hardiness. Studies are also being conducted on the effect of evaporation during the winter in causing injury to the wood of young orchard trees, both established trees and fall-planted trees. Several varieties of pecans and English walnuts are also being planted with a view of determining the hardiness for this climate, and a small planting of the American persimmon has been set for the same purpose. A number of species of apple have been planted with a view of working common varieties on them and determining their value as hardy stocks. The value of scion roots for varieties that are grown in cold sections, such as northeastern New York, is also being studied.

Fertilizers for strawberries and bush fruits.— A planting of currants, gooseberries, red and black raspberries, and blackberries has been started, and fertilization plots have been laid out, on the pomology grounds. Experiments with fertilizers for strawberries, red raspberries, currants, and gooseberries have been conducted on the farms of C. G. Velie and Sons, Marlboro, New York, during one season, and are to be carried on indefinitely. Plans have been made to conduct similar experiments with these fruits in sandy soil on the Dietz farm at Webster, New York.

Influences that affect the setting of fruit.— A thorough study is being made concerning the "June drop" as influenced by the condition of the tree as well as by the percentage of this fruit that has been pollinated.

Factors that influence the color of fruit.— A study is being made of the effect of shade on color during the early part of the growing period of such fruits as apple, peach, and pear, where the color is only in the skin and requires light for development. The effect of shade on such fruits as the plum and cherry, where the color is in the flesh, and the possible effect of various chemicals in intensifying color, is also being studied.

EXTENSION

The following represents the activities of the extension division during the past year:

Lectures (grange, association, field, and the like)	37
Demonstrations (pruning, spraying, and the like)	27
Inspections	26
Extension schools	5
Exhibits at state and county fairs	2
Miscellaneous	7

In addition to the activities mentioned above, the Department, in cooperation with the New York Central Railroad and the State Department of Agriculture, ran a train through the Hudson valley and western New York during late August and early September, in order to explain the operation of the new apple grading and branding law and to demonstrate the packing of apples under that law. Stops of approximately three hours each were made at twenty-nine places, and the average attendance was one hundred and sixty-three persons.

Another activity in which the extension division has been interested was a test of commercial fertilizers in an apple orchard at Wolcott, New York, with a view of determining the nature and amount of fertilizer adapted to the orchards of that community located on the same type of soil. Another line of work was the supervision of an orchard leased by the Boy Scouts of Cortland, New York.

A large amount of correspondence is carried on concerning such problems as can be solved without personal inspection, and this work will be further developed by offering a correspondence course in advanced fruit-growing as soon as details can be arranged.

In addition to the further development of the activities mentioned above, the Department hopes to pay more attention in the future to the marketing side of fruit-growing, to the receipts and prices of fruit on different markets and the distribution of these receipts throughout the year, and to a determination of the best practices for a given region. This information will be made available to the growers through extension schools and other agencies.

RECOMMENDATIONS

Among the larger items in which the Department is in need is, first, a cold storage plant. As the young experimental orchard increases in age, the cost of maintenance will greatly increase. Satisfactory returns from the orchard cannot well be secured without some sort of storage equipment. Further, the Department would like very much to conduct experiments in order to determine the killing temperature of various plants and fruits in storage. For this, of course, a room in which the desired temperature can be maintained is necessary.

Second, it is understood that the old barns on the Bool farm are to be removed. This will leave the Department with no room for packing fruit or for storing machinery. Unless such accommodations can be provided in the sheds to be built by the Department of Farm Practice, some provision will have to be made for packing and storage rooms.

Third, the Department has no greenhouse space. Some specimens of exotic fruit plants should be maintained in a conservatory so that they can be used in teaching the course in systematic pomology. A place is also needed where ordinary deciduous plants can be grown for special purposes in demonstrating lectures. It is believed that it would be very much to the advantage of all the plant industry departments if a large conservatory could be maintained under the direction of some one department, such as Floriculture. In this case the cost would be much less for the relatively small amount of material needed for some departments than if each department maintained a separate room for such purposes. The Department also desires a small amount of space in which to conduct experiments in a thorough study of the root growth of trees and bush fruits, and the bearing of such root growth on the pruning and fertilizing experiments.

C. S. WILSON,
Professor of Pomology.

DEPARTMENT OF FLORICULTURE

ESTABLISHMENT OF THE DEPARTMENT

Previous to October 1, 1913, the work in floriculture was given in the Department of Horticulture. During the summer of 1913 the Agricultural College Council established a separate Department of Floriculture. On July 26, 1913, the Council, on the recommendation of Dr. L. H. Bailey, invited the writer to head this new department. He began the work on September 1 of the same year.

CHANGES IN STAFF

Dr. A. C. Beal, who previously had had supervision of the teaching and investigative work, was early in the year relieved of most of the teaching so that he might devote more time to investigative and research work. A. C. Hottes, a graduate of Cornell University in 1913, was promoted from graduate assistant to instructor, with the expectation that he would devote the larger part of his time to work in investigation. Mr. Hottes received the degree of Master of Science in Agriculture in June, 1914. C. L. Thayer was appointed assistant in investigation on April 1, 1914. Mr. Thayer is a graduate of Massachusetts Agricultural College, class of 1913. Miss L. A. Minns, a graduate of Cornell University in 1914, was made instructor in the Department in May, 1914. Miss Minns' work is largely along the line of teaching amateur phases of flower growing, and that her work fills a need is made evident by the large number of students in the Department of Home Economics and in other courses who register for this work. David Lumsden, of New Hampshire Agricultural College, was made assistant professor in the Department on June 1, 1914. Professor Lumsden devotes his time principally to work in instruction and to supervising the practical operations in the greenhouses.

TEACHING

The Department has given instruction to approximately two hundred and sixty-eight students during the year. A comparatively small number of these, however, were specializing in strictly commercial phases of the subject. Of these a number of graduates were placed in desirable positions at the close of the university year.

The class work has been handicapped, due to the lack of suitable glasshouse space. Practical laboratory exercises were difficult to arrange for because of the large number of students registered in the different courses. This was especially true during the first semester, when the

laboratory for practical work was shared with the Department of Vegetable Gardening. As plans are now formulated for an increased glass area (made possible in 1912 by the state appropriation of $30,000 for this and other departments interested in work along the lines of plant industry), it is expected that the congestion will be considerably relieved.

During the early part of the year the Department was handicapped because of lack of field area near the college buildings which could be used for outdoor laboratory periods. Early in spring the Director assigned to the Department the area south of the Rural Schoolhouse. This, however, was very rough and infertile, but by considerable effort it was made fairly satisfactory, and even better results with garden flowers are anticipated for next year.

Practical work in greenhouses.— Work in the university range of greenhouses has been carried on along the same lines as in previous years. Because of lack of glass area suited to their culture, no work was attempted with roses or violets. During the year an excellent collection of orchids from the Philippines was loaned to the Department by Dr. A. B. Ward, head of the Pathological Division, Bureau of Plant Industry, Washington, D. C. This collection consists of about twenty-nine genera and one hundred and three species of the more valuable orchids. Instructional work in growing chrysanthemums, carnations, bedding plants, bulbs, and various miscellaneous plants has been carried on.

By terms of a contract made with A. C. Bool about May 1, 1912, the Bool greenhouses were purchased by the College of Agriculture. Possession of these, however, was not to be taken until October 1, 1914. Because of lack of space in the university range for growing many crops, such as roses, violets, bedding plants, sweet peas, antirrhinums, asparagus, maidenhair ferns, palms, and plants of a like nature, it was considered advisable to run these houses in a commercial way during the coming year; and in order to get the plants established and ready for winter flowering, the Department took possession of these houses on July 1, 1914. The plants in a house of grafted roses and in one of carnations are now coming into bloom. Approximately one thousand violet plants are well established and will bloom soon. The surplus of flowers and plants not needed for class exercises is sold at wholesale prices to retail dealers in the town.

INVESTIGATION

Investigation under the Adams Act

It is hoped that funds may be available for taking up some line of original investigation under the Adams Act. The following problems are suggested: abridging the rest period of plants; preserving cut flowers;

effects of electricity on plant growth; studies in rose propagation; and the effect of artificial light on plant growth. Five hundred dollars should be appropriated for beginning these investigations.

Other studies

The following lines of investigative work have been carried on during the year:

Gladiolus studies.— The study of the species and varieties of gladioli, undertaken in cooperation with the American Gladiolus Society, has been continued. A much larger collection was grown this year, and a large number of additional descriptions and photographs were made. It is believed that sufficient material has been collected to warrant publication.

Rose studies.— The Department, in cooperation with the American Rose Society, is establishing a test garden of roses. The purpose of the rose garden here is to determine the hardiness of the different varieties of cultivated roses under New York conditions. It appears that most of the roses used for garden planting in the northern United States are grown and handled by nurserymen in this State, and it is believed that the rose tests here will be of great value to all interested in growing roses. The original collection of climbing roses, planted two years ago, has been included in the test. There are now about three hundred varieties growing on our grounds, and the collection will be increased by donations from the growers. Several species have been planted, and it it planned to add other hardy forms. In connection with this work, studies in propagation, fertilization, and pruning of roses in order to secure the best results, will be undertaken.

Sweet pea studies.— Last year it was thought that with the publication of the bulletin on varieties, the work on sweet peas was practically completed. The Department, however, has been urged by the American Sweet Pea Society to continue studies on the waved class of sweet peas, both out of doors and under glass. The work that has been done here has received the commendation of the leading authorities on sweet peas, and it seems advisable that if further studies are to be made the work should be conducted under the same conditions as the previous work. It is now planned to concentrate energies on the study of the waved type. Additional experiments should be made in the preparation of the soil for growing sweet peas.

Aster studies.— The study of varieties and types of the China aster was continued this season. As soon as the results warrant, a publication will be issued.

Phlox studies.— This year a collection of four hundred varieties of the species of herbaceous phlox was planted. It is hoped that a complete collection can be established for making a thorough, systematic study of this important group. The season has been very favorable, and the work is very promising. An old collection of about one hundred varieties afforded excellent material this year for preparing descriptions as a basis for future work.

Iris studies.— A large collection of varieties of the German and similar types and species of iris has been planted. This collection will be added to as rapidly as possible and will form the basis of a study of this important garden plant.

Peony studies.— The large collection of varieties of peonies has become reestablished on the new site to which it was recently moved. The collection is undoubtedly the largest one of correctly named varieties of peonies in the world, and this should prove to be of great value to peony specialists in correcting the nomenclature of their varieties. That they are aware of the fact is seen in the increased use they make of the collection each year.

Hardy chrysanthemum studies.— The Department is cooperating with the United States Department of Agriculture in testing varieties of hardy chrysanthemums.

Other flower studies.— A study has been undertaken of the species and varieties of aquilegia. Other flowers are grown each year and information is being gradually collected on a number of flowers. Monographic studies of other important groups are planned, but these must await investigation by graduate students who may come later.

Greenhouse investigations.— The Department is seriously handicapped in not having greenhouse facilities for the investigation of problems affecting the growth of flower crops under glass. The appeals for assistance are more frequent each year, and it is hoped that the State will provide without further delay suitable greenhouses for the solution of these problems, which are giving the florists great concern.

Greenhouse survey.— The floricultural interests of the State are larger than those of any other State, but there is a great lack of definite information as to the extent of the industry. Last year a survey of Long Island was undertaken, but with the other work in hand this section was not completely covered. While much of the data of such a survey may be difficult or impossible to compile, yet much useful data can be gathered. Moreover, the conditions are discovered, the problems are ascertained, and the Department is in a position to give more valuable assistance to the florists of the State. The work is investigative, at least in so far as the ascertaining of the conditions and problems is con-

cerned, although in some lines it may be regarded as extension work. In floriculture the investigative phase is perhaps more important, at least until such time as we have results from comprehensive greenhouse experiments.

EXTENSION

It is hoped that an appropriation of $500 may be set aside from extension funds for lectures before women's clubs, gardening clubs, farmers' clubs, and granges. It is also hoped that some work may be done in connection with extension schools and in assisting commercial florists and nurserymen through the results of investigative work conducted at the College.

Public exhibitions and decorative work.– Two public flower exhibitions have been held during the year. On November 1, 1913, a very satisfactory chrysanthemum exhibition was held in the headhouse connected with the greenhouses. In addition to the chrysanthemums grown at the College, a large number of specimens were contributed by prominent growers. There was also an exhibition by the students, of table decorations, formal designs, and other floral work. A second exhibition was held during Farmers' Week.

The Department has assisted during the year in making various public functions of the College of Agriculture more attractive through hall and table decorations. Among these were decorations for the agricultural banquet, the assemblies, class banquets at the Home Economics Building, the Comstock Memorial, and the dedication of the Forestry Building. This work was done in most instances without charge.

E. A. WHITE,
Professor of Floriculture.

DEPARTMENT OF VEGETABLE GARDENING

The Department of Vegetable Gardening was organized on October 1, 1913, with the following staff:

Paul Work, Superintendent and Instructor; A. E. Wilkinson, Extension Instructor; H. W. Schneck, Instructor; C. E. Dimon, Instructor; Jesse Stickler, Assistant Gardener. W. W. Knudson was appointed as instructor on February 1, 1914, and at the same time Moe Spiegel came to the Department as gardener.

TEACHING

The following courses have been offered during the year:

Course	Subject	Term	Number of students receiving grades
3	Commercial Vegetable Gardening	1	22
4	Vegetable Forcing	1	15
5	Systematic Vegetable Crops	1	4
6	Practice	1	1
7	Undergraduate Research	1	2
1	Home Vegetable Gardening	2	25
2	Commercial Vegetable Gardening	2	19
3	Commercial Vegetable Gardening	2	11
4a	Vegetable Forcing	2	1
6	Practice	2	2
7	Undergraduate Research	2	2
8	Advanced Vegetable Gardening	2	6
5	Systematic Vegetable Crops	3	7
7	Undergraduate Research	3	5
Winter course			
1	Commercial Vegetable Gardening	....	6
2	Vegetable Forcing	....	11
3	Home Vegetable Gardening	....	35
Summer school			
A	Vegetable Gardening	....	13

During the past year a full scheme of prerequisites to vegetable gardening courses has been enforced for the first time. The result is a smaller enrollment, but a much more satisfactory standard of work due to better preparation. Almost all the students enrolled are upperclassmen.

The establishment of the third term marks a notable advance in the teaching of vegetable gardening. It is now possible for course work to

coincide with the growing season of the plants, and laboratory studies may be continuous from seed to maturity.

Particular attention is being bestowed on the courses for specialists, with the object of supplying well-equipped men to fill the positions that are opening in larger numbers each year. The requirements are being made more and more rigid each year in order to correspond with the advancing standards by which applicants are measured. Each student is expected to spend a spring and a summer in commercial production, and he is required to be well advanced in the fundamental sciences before he undertakes the courses in applied science.

The gardens have been used almost entirely for instructional work. The garden at Craig Field is used for crops that mature late and are grown under the more extensive methods. The early crops are planted at East Ithaca, where conditions are much more favorable for intensive vegetable production. Here are located the individual student gardens, the gardens for systematic material, undergraduate research plots, and demonstration plots of various sorts. An acre of this garden is now equipped for overhead irrigation, and the pipes are to be extended as rapidly as possible.

INVESTIGATION

The muck-land experiment, which was established in 1911 at South Lima and in 1912 at Canastota and Clyde, has been maintained. Records have been taken each year, and tentative results should be forthcoming before long. The sincerest appreciation from the College is due to the cooperators, Messrs. Ellis, Hay, and Jennings. During the past year cooperative experiments have been conducted with cauliflower on Long Island, and with greenhouse cucumbers at Elmira. In these experiments, also, the able assistance of the cooperators has made the work possible.

Mr. Knudson has carried through a test of different methods of training tomatoes. This is an old subject, but no results yet published represent an experiment as thorough as this one. Costs, as well as advantages and disadvantages, have been fully considered.

Mr. Schneck is making a thorough study of hothouse lettuce-growing, including an experiment with bottom heat and a test of strains of Grand Rapids.

A vegetable survey of the State has been projected for four years, but almost nothing has been undertaken. Such a survey should consist, first, of a rapid view of the State in order to determine the location and relative importance of the producing districts, and second, of detailed surveys of individual crops in order to show the conditions and methods of production, together with the costs and returns. Such material is of inestimable value in making possible a full coordination between investigative projects and field conditions.

EXTENSION

The extension instructor has been more than busy during the year in meeting the demands on his time and energy made by the home and commercial gardeners of the State. He has attended extension schools, delivered lectures, conducted conferences, consulted with producers in the field, and directed simple experiments for the benefit of individual growers. Exhibits have been shown at a number of fairs. Assistance has been afforded in school garden and club work. A Reading-Course lesson, *Planting the Home Vegetable Garden*, has been added to the home garden series. In addition, a large correspondence has been cared for, and many inquiries have been answered. The crop-accounting system which has been in use for two years was maintained on a small scale. This work offers splendid possibilities, and merely awaits opportunity to carry it forward.

The New York State Vegetable Growers' Association holds its annual meeting at the College of Agriculture during Farmers' Week. The Department has cooperated in the arrangements for this meeting, as well as in the other work of the organization, the superintendent of the Department serving as its secretary.

RECOMMENDATIONS

The vegetable producers of New York, as in other States, have in the past been slow to look to the College for help. The possibilities of usefulness have been brought to their attention in many ways within the past four years. Their interest has been aroused. The demands which have been awakened must be met if the College is to maintain its position of usefulness and influence with this most important and much neglected group of producers.

The most serious and vital need in vegetable gardening to-day is research that will not be satisfied with the recording of superficial conditions, but that will seek to know fundamental relations and governing factors. For this purpose a high-grade man combining practical experience and scientific training should be employed in the Department.

Conditions at Ithaca are quite different from those prevailing in sections from which the most urgent calls arise, and the first worker employed should devote most of his time to studies on Long Island and on the muckland and upland gardens of western New York. The exact nature of the projects to be undertaken would have to be determined in the light of full study of the conditions existing. It is already evident that the Long Island growers stand in most urgent need of assistance with respect to the feeding of their vegetable crops and the maintenance of fertility in their gardens.

The profits and costs incident to the production of crops for the cannery should be studied. This phase of the industry should be placed on a sounder basis of profit.

At the College the need of increased greenhouse space is seriously felt. The vegetable range that has been planned should be speedily completed to its full extent of nine fifty-foot units and a headhouse. The forcing industry in the State is of exceeding importance, and the rapidity with which market gardeners have been installing greenhouses within the last three or four years is little short of startling. It would be unfortunate, in view of the large number of crops grown under glass and the importance of plant production, to curtail this range, which has been planned to meet the absolute minimum for teaching purposes. Before many years a research range at some other point on the college grounds will be required.

An increase in the area of the East Ithaca garden is imperative if the work of the Department is to make satisfactory progress. The introduction of the third term permits students to spend a larger proportion of their time in field laboratory work. Though no effort is being made at present to enlist graduate students in this Department, a number are enrolled, and these require facilities for outdoor work. Craig Field seems to be unsuited to the production of many of the crops.

The old barn at Craig Field not only is unsightly, but is entirely inadequate for the accommodation of the tools and equipment of the Departments of Floriculture, Pomology, and Vegetable Gardening. The structure contains a large amount of useful material that should be taken down and reconstructed into one or more buildings to fill this need.

PAUL WORK,

Instructor in Vegetable Gardening and Superintendent of Department.

DEPARTMENT OF FORESTRY

FACULTY

During the year two professors were added, and one professor resigned. Professor F. B. Moody began his work on October 1, 1913. Professor Walter Mulford resigned, his resignation becoming effective on September 30, 1914; in his place Professor R. S. Hosmer was appointed, beginning his work on October 1, 1914

EQUIPMENT

The Forestry Building was formally opened on May 15, 1914. A large number of foresters from various parts of the United States and Canada were present. The proceedings of the meetings held at this time will appear as a university publication. The building was first used for instructional purposes in the latter part of April, 1914.

At the dedication of the Forestry Building, announcement was made of a gift of $500 from Mr. Charles L. Pack of Lakewood, New Jersey, President of the Fifth National Conservation Congress. Mr. Pack stated that this money should be used for any purpose which the Department of Forestry deemed best. It is the intention of the Department to hold this money as a permanent fund, the income of which shall be offered annually to undergraduates as a prize in some line of forest research.

TEACHING

Twenty-six courses of instruction were given during the year, as follows: first term, twelve; second term, eleven; winter course, one; summer school, two.

The number of students registered in these courses was as follows:

Course	Subject	Term	Number of hours credit	Number of students registered
1	Farm Forestry	1	2	25
1	Farm Forestry	2	2	24
2	Elements of Forestry: Mensuration, Utilization, and Management	1	3	58
3	Elements of Forestry and Silviculture	2	3	32
6	The Field of Forestry	1	2	40
8	Wood Technology	2	2	40
9	Forest Utilization	1	4	26
10	Engineering	2	2	26
11	Forest Mensuration	2	5	11
13	Timber Trees and Forest Regions	1	3	7
14	Silviculture: Forest Ecology	1	3	15

Course	Subject	Term	Number of hours credit	Number of students registered
15	Silviculture: Natural Reproduction and Care of the Forest	2	3	13
16	Silviculture: Forest Planting and the Forest Nursery	2	3	10
18	Forest Protection	1	2	10
19	Forest Policy, Forest Law, and History of Forestry	1	2	13
20.	Forest Management	1	5	5
21.	Forest Administration	2	3	5
22.	Seminary	1	2	5
22.	Seminary	2	2	5
23.	Advanced Work	1	2	4
23.	Advanced Work	2	2	5
24.	Research	1	3	7
24	Research	2	3	4
			63	390
Winter course 1	Farm Forestry	......	....	57
Summer school B	General Forestry	......	2	23
C	Forestry for Schools	....	2	5
	Total (all courses)	......	.....	475

One student received the degree of Master in Forestry in June, 1914; two others completed the work but have not yet received the degree.

In order to avail itself of the third, or summer, term of instruction in the College, the Department has arranged to give, in the summer term of 1915, certain courses now given in the fall and spring terms: Course 9, Forest Utilization (for professional students); Course 11, Forest Mensuration; Courses 14 and 15, Silviculture; and Course 20, Forest Management. All these courses require a large amount of field work on a forest tract, and this can be done to better advantage in the summer than at other seasons of the year.

INVESTIGATION

The following investigative work is under way:

Experimental cuttings on plots in woods belonging to the Veterinary College, in order to liberate reproduction and to ascertain its ability to recover from suppression.

The fencing-off of a section of the woods belonging to the Veterinary College to exclude grazing, in order to determine the effect on reproduction.

Tests of the accuracy of log rules as applied to felled timber in a central

New York operation. (Results published in "Forestry Quarterly," Volume XII, No. 3, p. 390–394.)

The preparation of a detailed working plan for the management of the 106 acres of woodland under the control of the Department.

The beginning of a complete and annotated bibliography of forest organization literature in the University Library.

The beginning of tests on the relative durability of treated and untreated fence posts set on the university woodlots.

Preliminary tests in an investigation of germination of forest-tree seed.

Planting of additional species of hardwoods on the experimental planting area at the Behrend farm.

Experimental planting of white pine in openings in the woods belonging to the Veterinary College, in order to ascertain the relative value of artificial regeneration as compared with natural.

Thirty thousand additional trees planted at Varna on the reservoir site of Cornell University.

EXTENSION

Extension work in forestry is being developed along the following lines: (1) lectures; (2) cooperation with city water boards and others in planting; (3) woodlot and timberland examinations.

Fifteen woodlots, aggregating 836 acres, were examined in the course of the year, and assistance in forestry practice was given the owners. Instruction in forestry was given at extension schools, farmers' institutes, and granges, and in connection with the farm demonstration train on the Ontario & Western Railroad. In the summer of 1914 a special study of the woodland in Broome and Dutchess Counties was made by Professors Moody and Bentley, for the purpose of obtaining definite data for the assistance of private owners in practicing forestry. In addition to assistance of the owners by examination of their land and preparation of plans for their guidance, assistance has been given to a large number of persons by correspondence. The extension professor has devoted one third of his time to instruction at the College in farm forestry, course 1.

A typical example of the cooperative work with city water boards is that with the city of Cortland, for which the Department is making a planting plan for land owned by the city in the Cortland watershed, which is the source of the water supply for that city. The planting will extend over a period of five years and will be under the supervision of the Department of Forestry.

The more important features of a planting plan are: location; area of different sites to be planted; purpose of plantation; detailed recommendations for planting, including cost of plant stock, cost of planting, method of planting, care and protection, species and spacing; and method of subsequent treatment.

Plans are now being formulated with several woodlot owners whereby their woods will be used as demonstration areas for the community, to serve as examples of the best methods of forestry practice. Through this cooperation the woods are placed under the management of the Department of Forestry, and all recommendations are carefully followed by the owner. Sample plots are being established as rapidly as possible, in which the following lines of investigations will be carried out: growth and yield of stands, natural reproduction, sprout reproduction, artificial reproduction, effect of thinnings, effect of fires, effect of grazing.

Requests for advice as to the proper methods of handling woodlots and timber tracts are increasing rapidly. In such cases, a personal examination is made in company with the owner, tenant, or farm superintendent, and when the tracts are small, say up to 100 acres in extent, the entire area is carefully cruised and such trees are marked for cutting as would bring about the desired results from a forester's standpoint. The wishes of the owner, and the age, density, and conditions of the forest, are the main factors that determine the methods of management to be applied. Such features are incorporated in a report to the owner of the property, and include location and area of woods, species, condition, past history of the stand, timber and wood estimate, markets, and methods of management. The cost of all cooperative work in forest planting and woodlot examination must be borne by the owner or applicant, and includes only that of travel and other expenses.

RECOMMENDATIONS

Now that the Department of Forestry is adequately housed, two main needs for the future stand out clearly. The first is for better facilities for conducting forest research, particularly in wood technology and in silviculture. The second is for a college forest.

The adjustment of the forestry curriculum to meet the requirements of a three-term schedule makes necessary an addition to the teaching staff. The men so added should be qualified to engage in research work. It is recommended that two men be appointed.

In his report for 1912-1913, Professor Walter Mulford urged the necessity of securing a tract of two to three thousand acres of forest land to be used (1) as a forest experiment station, (2) as a demonstration forest, illustrating various methods of forest management, and (3) as a place in which to give forestry students drill in forest operations on a scale large enough to be typical of true forest work. The passing months have made increasingly evident the need for such a forest. The writer adds his urgent recommendation that provision be made for it.

RALPH S. HOSMER,
Professor of Forestry.

DEPARTMENT OF ENTOMOLOGY

RETIREMENT OF PROFESSOR COMSTOCK

The year has been marked by the retirement of John Henry Comstock, Professor of Entomology and head of the Department.

Beginning as an undergraduate in charge of a special class in entomology, Professor Comstock has devoted over forty years to the building of a department which under his guidance was known the world over as a center for entomological instruction. Though he has always insisted that training in the pure sciences must precede and underlie the study of the practical applications of the subject, Professor Comstock has always been thoroughly sympathetic toward the economic aspects of entomology. Both by his own research and by his teaching, he has done much to develop the work in economic entomology throughout the country.

It is not alone as a teacher of entomology that Professor Comstock has helped the University. Through his broad interest in educational matters, and his sympathetic and unselfish attitude toward problems affecting the general welfare, he has had a strong influence in shaping the educational policies of the College of Agriculture and the University.

In commemoration of the work that he has done for the University and as a token of the deep personal regard that he has won, the occasion of his retirement was marked by the presentation of a fund of $2500 from his former students, to serve as the nucleus for a Comstock Memorial Library in Entomology.

Fortunately, Professor Comstock's influence and council will not be lost, for, as Emeritus Professor of Entomology, he retains his room in the Department, and will there bring to a completion some of the important problems of research and the textbooks that he has under way.

REORGANIZATION OF THE DEPARTMENT

Professor Comstock gave much attention to the question of the reorganization of his Department at the time of his retirement, and his recommendations were accepted almost without change by the President of the University and the Board of Trustees. In brief, the plan is as follows:

The Department remains as a unit. The interests of the students and of the College can best be served by a united Department rather than by segregation of the various phases of the work.

Dr. James G. Needham succeeds Professor Comstock as head of the Department. In his own teaching work he will develop primarily the biological aspects of entomology, a field in which he is a noted worker.

Professor Glenn W. Herrick is made Entomologist of the Experiment Station, and under the direction of the head of the Department is to have immediate charge of all the work of the division of economic entomology, except such extension work as shall be assigned by the head of the Department to the Extension Professor of Entomology.

Assistant Professor Oskar A. Johannsen is raised to the rank of Professor of General Biology. He is to have immediate supervision of all the work in general biology.

The writer, W. A. Riley, continues his work in insect morphology and parasitology, and in Dr. Needham's absence is at present serving as acting head of the Department.

TEACHING

The courses of lectures and laboratory work, thirty-two in number, as listed in the Announcement of the College for 1913-1914, were all given and were well attended. In addition there were offered fourteen courses in the summer term, and with few exceptions these were overcrowded.

There was a marked increase in the number of students taking work in the Department. The current enrollment, by courses, is over 1560. Practically all these students are taking laboratory work.

INVESTIGATION

As usual, the members of the departmental staff have devoted as much time as possible to special investigations, either as independent problems or, more commonly, in connection with their teaching work.

Much of the research work of the Department is intimately connected with the instructional work. Graduate students and exceptional undergraduates are assigned problems, which are worked out under the direct supervision of the professor with whom the students have been registered. In most cases, the results of this work are in direct proportion to the time and attention which the professor is able to devote to the problem.

For the same reasons, an important part of the research work of the professors in the Department is embodied in textbooks, reference books, and lecture and laboratory outlines. A list of the more important of these published or completed during the year is as follows:

Needham, J. G. The natural history of the farm, p. 1–348, figs. 1–140.

Riley, W. A., and Johannsen, O. A. A handbook of medical entomology, about 400 pages. (To appear this fall.)

Herrick, G. W. Household insects, p. 1–470, figs. 1–152, pls. 1–8.

Crosby, C. R., and Slingerland, M. V. Manual of fruit insects, p. 1–503, figs. 1–396. (The extension and completion of a volume projected by the late Professor Slingerland.)

Bradley, J. C. A manual of scientific literary methods. (A text developed in connection with Dr. Bradley's course in literary methods and technique of entomological work.)

Comstock, Anna Botsford. The tree notebook, p. 1–160; illustrated. (For schoolroom study and field observation.)

Comstock, Anna Botsford. The bird notebook. (Published in two volumes of 123 pages each, with text figures and 54 plates by Louis Agassiz Fuertes.)

Comstock, Anna Botsford. The pet book, p. 1–350, figs. 1–121. (A guide to the care of not only the ordinary pets, but more especially the native wild animals occasionally kept in captivity. In press.)

In addition to those mentioned above, there are a number of works of similar nature in course of preparation. Among these may be mentioned:

Comstock, J. H. The wings of insects. (Bringing together and correlating his work of the past twenty years.)

Crosby, C. R., and Matheson, R. Manual of vegetable insects. (In preparation.)

Needham, J. G., and Lloyd, J. T. The life of inland waters. (A manual of limnology.)

Needham, J. G., *et al.* A series of handbooks on aquatic insects.

The following books, several of which are nearing completion, are being developed in collaboration with various graduate students:

Riley, W. A. The essentials of insect histology. (Primarily for use in a course designed for those planning research work in entomology.)

Bradley, J. C., Crosby, C. R., Johannsen, O. A., *et al.* A list of the insects of New York State. (This important work is being carried on in cooperation with the State Entomologist and leading entomological societies and museums of the State. It will prove of very great value in the economic and systematic work.)

Embody, G. C. A textbook of fish culture. (This book will set forth the principles upon which modern fish culture is based.)

The results of several pieces of investigation by members of the staff of the Department and by advanced students have been published in briefer form, or are completed for publication. A list of the more important of these is given below. Many short communications that have appeared in agricultural papers, scientific journals, and leaflets, are omitted from this list.

Johannsen, O. A. *Sciara congregata* sp. nov. (Diptera). Psyche **21**: 93.

Crosby, C. R., and Leonard, M.D. The tarnished plant-bug. Cornell Univ. Agr. Exp. Sta. Bul. 346.

Comstock, Anna Botsford. (Constant contributor to the Cornell Rural School Leaflets and to the Nature Study Review.)

Embody, G. C. Fish meal as food for trout. Amer. Fisheries Soc. Trans. **1914**.

Matheson, R. Life history of a dytiscid beetle (*Hydroporus septentrionalis*). Can. ent. **46**:37–40.

Matheson, R. Life history notes on two Coleoptera (Parnidae). Can. ent. **46**:185–189.

Matheson, R. Notes on *Hydrophilus triangularis*. Can. ent. **46**:337–343.

Matheson, R. The San José scale in Nova Scotia. Journ. Econ. Ent. **7**:141–147.

Lloyd, J. T. Lepidopterous larvae from rapid streams. New York Ent. Soc. Journ. **22**, No. 2, June 1914.

Lloyd, J. T., and Alexander, C. P. The biology of North American crane flies (Tipulidae, Diptera). The genus Eriocera Macquart. Pomona Journal of Entomology and Zoology, Vol. vi, No. 1, March 1914.

Lloyd, J. T., and Lloyd, J. U. Coca, "The Divine Plant of the Incas." Journal of the American Pharmaceutical Association, 1913. Copied in the Druggist Circular, November 1913, Revista Americana de Farmacia y Medicina, December 1913, and Revista Dental, May 1914.

Alexander, C. P. Neotropical Tipulidae in the Hungarian National Museum (Diptera) iii. Ent. news **25**:205–215, 351–362.

Alexander, C. P. On a collection of crane flies from British Guiana (Tipulidae, Diptera). Amer. Ent. Soc. Trans. **40**:223–255.

Alexander, C. P. New or little known neortopical *Hexatomini* (Tipulidae, Diptera). Psyche **21**:33.

Alexander, C. P. Numerous other short articles on the preceding group.

Coutant, A. F. The life history and habits of a blood-sucking Muscid larva.

Crawford, D. L. A recently described Psyllid from East Africa. Ent. news **25**:62–63.

Crawford, D. L. A monograph of the jumping lice or Psyllidae of the New World. U. S. Nat. Mus. Bul. 85:1–186.

Funkhouser, W. D. Some Philippine Membracidae. Ponoma journ. ent. and zool. **6**:67–74.

Gilmore, R. J. An ecologic study of the fresh-water molluscs of the Cayuga Lake Basin.

Kephart, Miss C. F. The poison glands of the larva of the browntail moth (*Euprostis chrysorrhoea* Linn.). (In press.)

Leonard, M. D. A bibliography of the writings of Professor Mark Vernon Slingerland. Cornell Univ. Agr. Exp. Sta. Bul. 348.

Moore, Miss Emmeline. The Potomagetons in relation to pond culture.

Noyes, Alice A. The proventriculus of a Trichopterous larva. (In press.)

Pratt, Miss Emilie. A study of the fauna of an alga mat.

Smith, Miss Cora A. The development of *Anopheles punctipennis* Say. Psyche **21**: 1–19.

Smith, Miss Lucy B. Studies of North American Plecoptera.

A valuable part of the work of the Department consists in making available the facilities for visiting entomologists. The aid which can thus be given is fully recompensed in the way of materials, publications, and the like, which these men are glad to contribute to the Department. During the past year, extended stays were made by the following gentlemen:

Dr. Antonio de Soveral, of the Portuguese Medical Service, was here for about three months, selecting especially work bearing on problems of the relation of insects to disease.

Messrs. A. H. Ritchie and C. W. Mason, Fellows on the Carnegie Entomological Research Fund of the British Government, spent at Cornell their entire time allotted to residence study. Mr. Ritchie expects to continue his work here this fall unless recalled.

Dr. G. F. White, expert in bee diseases, from the United States Bureau of Entomology, spent three months at Cornell, devoting half of his time to studies in insect histology bearing on his special field.

During the year three students from the Department have been appointed to important government positions in the Union of South Africa. This makes a total of six that the Department has sent to that region within the past twelve years. A request that two more men, of Professor Comstock's own choosing, be sent, could not be complied with.

One graduate student was appointed Government Entomologist of Nyassaland.

The demand for graduate students to fill positions in this country continued greater than could be met.

EXTENSION

The extension work of the Department has been conducted by Professors Herrick and Crosby. Both have found the correspondence unusually heavy during the year, and it has taken a large part of time and energy.

Professor Herrick made many visits during the year to the orchards of fruit growers in order to consult and advise with them regarding the control of certain pests. Some of these visits developed into field meetings where dozens of fruit growers congregated for the purpose of consultation and advice. At least three visits were made to the hop-growing regions of New York.

Several visits have been made to regions of infestation by the lesser migratory locust, for the purpose of advice regarding methods of controlling its ravages.

Under Professor Herrick's direction, three field stations, with a capable young man in each, were successfully maintained during the year in different parts of the State. They were devoted to a study of the fruit-tree leaf-roller, to insects causing injury to the fruit of the apple tree, and to insects of the hop.

Professor Crosby's work of the past year has been conducted in close cooperation with the Department of Extension Teaching. He has attended a number of extension schools and has given a series of lessons on the control of insect pests. Farm visits and demonstrations were made in cooperation with two of the farm bureau agents, and cooperative experiments in the control of flea beetles and the corn-ear worm were conducted on Long Island. The exhibit of injurious insects, which has been increased in size and improved in many ways, was shown at the winter meetings of the New York State Fruit-growers' Association and the Western New York Horticultural Society, at the State Fair, and at the Rochester Industrial Exposition, as well as at a number of county fairs.

In cooperation with the Chase Brothers Company, of Rochester, Professor Crosby directed experiments against the tarnished plant-bug on nursery stock. For this work a graduate student was kept in the field from June 1 to August 1. Two leaflets have been prepared, one dealing with methods of control of the army worm, the other with the cabbage aphis.

RECOMMENDATIONS

It has become absolutely impossible to conduct the work of the Department properly in the crowded quarters at its disposal. As already mentioned, the current registration is over 1560 students. Practically all of these are taking laboratory work. In laboratory work a minimum period is two and one half hours a week, and some of the students are putting in as much as twenty-five or thirty hours a week.

The Department has available for departmental use the third floor of Roberts Hall, and it shares the fourth floor with the Weather Bureau. Allowing for office rooms, library, and storerooms, an attempt is made to accommodate the students by keeping the laboratories open at all hours. It is recommended that steps be taken to secure the erection of the proposed building for this Department at the earliest possible time.

The writer would also repeat Professor Comstock's recommendation of last year, that as soon as possible provision be made for establishing courses in beekeeping. Professor Comstock pointed out that this important phase of the entomological work is entirely ignored by the educational institutions and experiment stations of the State. There is a strong demand for instructional work, and there are numerous requests from farmers and beekeepers for information concerning the diseases of

bees and related topics. The Department of Entomology should be abl to afford the best possible aid along these lines.

An experimental fish hatchery is urgently needed for the proper develop ment of the work in aquiculture. The economic bearings of this subjec are so important that the plans have already been presented in a detailed report.

So, also, the general needs of the Department have been the subject o a special report submitted according to instructions. The writer woul only add here that no provision has been made for the maintenance of th third term, which was inaugurated this year and which is destined to be a very important term in the work of the Department. In the future th Department must be maintained for three terms instead of two, and th writer would ask that this be considered in the distribution of funds.

WILLIAM A. RILEY,

Professor of Insect Morphology and Parasitology, an
Acting Head of the Department of Entomology.

DEPARTMENT OF DAIRY INDUSTRY

TEACHING

Regular courses.— The courses of instruction given in the Department during the past year have been the same as outlined in the report for 1912–1913. Because of the increase in the number of students desiring certain kinds of dairy work, it has been necessary to repeat certain courses during each semester. The total number of students registered in courses offered for the entire year is 737. The distribution of these students in the different courses is as follows:

Course	Subject	Number of students registered
1	Milk Composition and Tests (given both semesters)	199
2	Butter Making	42
3	Cheese Making	18
4	Elementary Bacteriology	54
6	Market Milk and Milk Inspection	123
7	Advanced Testing	30
8	Dairy Bacteriology	30
9	Advanced Butter Making	14
10	Fancy Cheese Making	9
12	Seminar (given both semesters)	29
13	Research (given both semesters)	19
14	General Agricultural Bacteriology	62
15	Bacteriology for the Home	45
16	Milk Composition and Tests (for special students, given both semesters)	26
18	Butter Making (for special students)	10
19	Advanced Cheddar Cheese Making	1
	Graduate students	26
	Total	737

It is of interest to note that the number of students registering for dairy work has increased from a total of 310 in the year 1909–1910, to 737 during the year just closed.

The Department offered course 1 during the third, or summer, term, and 14 students registered.

Five students took the course in dairy work given during the summer school.

Winter-course instruction.— For some years the number of students taking the winter course has reached the capacity of the Department. This year 107 students took the course. In addition to these students, who took

the regular twelve-weeks Winter Course in Dairy Industry, other students who were registered for the Winter Course in General Agriculture took dairy work as follows:

Subject	Number of students registered
Testing Milk and Its Products	16
Dairy Mechanics	1
Dairy Chemistry	3
Dairy Arithmetic and Bookkeeping	4
Farm Butter Making	36
Market Milk and Milk Inspection	29
Total	89

The one-week course for butter- and cheese-factory managers was given again this year. Five students took this course. Although a comparatively small number of men come to the College for this course, it is believed to be of great value because of the fact that all the men who take the work are in charge of factories and have a marked influence on dairy work in their home communities.

After the close of the twelve-weeks winter course, a special ten-days course was offered for the members of the regular winter course who desired to get additional work in the making of fancy cheeses and ice cream. Both these lines of work are increasing in importance in this State, and the Department is called upon to recommend men for positions in the manufacture of both these dairy products. Seven students took this course.

The total number of students registered in the Department during the year is 964.

INVESTIGATION

The Department has no person whose time is devoted primarily to research work, but all members of the staff are carrying on investigations as time and facilities permit. During the past year, active work has been done along the following lines of research:

Methods of making fancy cheeses. (A bulletin has been written on this subject, which is now in press.)

Efficiency of Endo's medium in detecting members of the colon group of bacilli.

Tests for the percentage of water, fat, and casein in butter. (Not yet completed.)

Farm butter-making. (Reading-Course Lesson for the Farm, published in March, 1914.)

Metallic flavor in butter. (Not yet completed.)

Factors influencing the percentage of fat in cream from the modern separator. (Nearly completed.)

Two factors influencing the weight of print butter. (Nearly completed.)

Inexpensive methods of cooling milk. (Nearly completed.)

EXTENSION

One member of the departmental staff, Mr. H. L. Ayres, devotes his entire time to extension work. He devotes his time to teaching during the winter course, and the remainder of the year works among former winter-course students and the dairy plants and dairy farmers of the State. Frequently members of the Department have given lectures at institutes, granges, and dairymen's meetings. Exhibits have been prepared and maintained at a number of county fairs, as well as at the State Fair.

The cow-testing-association work, which has been under way for a number of years, has been continued. This is true also of the market-milk-inspection work in connection with the Ithaca Board of Health. The Department also tests, free of charge, samples of milk for chemical composition and bacterial counts. The educational scoring of dairy products has also been continued during the year.

The Department is called upon for a very large amount of correspondence in connection with the dairy interests of the State, which requires considerable time from the members of the staff.

W. A. STOCKING, JR.,
Professor of Dairy Industry.

DEPARTMENT OF ANIMAL HUSBANDRY

TEACHING

The following table shows the registration in the various courses in this Department during the year 1913-1914:

Course	Subject	Number of students registered: First term	Number of students registered: Second term
1	Principles and Practice of Feeding Animals	169	195
2	Principles of Animal Breeding	122	112
3	Elementary Stock Judging	143	......
5	The Horse	.	146
6	Practical Horse Training	17	......
10	Dairy Cattle	117	......
11	Beef Cattle, Sheep, and Swine	47	......
15	Advanced Course in Principles of Feeding	..	31
16	Advanced Course in Principles of Breeding	13	12
17	Advanced Animal Husbandry	11	16
		639	512
Winter course			
1	Feeds and Feeding	282	
2	Breeds and Breeding	96	
3	The Horse	92	
		470	
Summer school			
A	Principles and Practice of Feeding Animals	34	
B	Principles of Animal Breeding, and Elementary Judging	19	
		53	

In addition to the number of students given in the table, there were four or five graduate students taking work in this Department. In the main, the progress made by the students in the various classes was satisfactory and there was a comparatively small number of conditions and failures. The additions made to the staff, notably Professor Hopper and Mr. Seulke, have added materially to the officers of instruction.

INVESTIGATION

The investigative work of this Department is very largely continuous in nature, and most of the work as given in the report made to the Director

two years ago has been continued although it has not seemed wise to publish any results in bulletin form. In addition to the work already planned, it it is hoped that the Department will be able to undertake some careful work along the lines of animal nutrition, the completion of the new building having increased the facilities for laboratory work of this nature.

EXTENSION

The appointment of Professor H. A. Hopper as Professor of Animal Husbandry having charge of extension work, has added materially to the capacity for work along this line. Professor Hopper has been employed very largely in instruction in extension schools, and it is planned that during the coming year he will be even more continuously engaged in this work. After the close of the extension schools last spring, Professor Hopper, with the aid of Mr. F. E. Robertson, the County Agent for Jefferson County, made an extensive examination of the cost of milk production in that county. The results of this survey are nearly ready for publication. The Department of Animal Husbandry has been represented during the past year at six district and county fairs and at the State Fair. At most of these fairs, educational exhibits were presented. About fifty lectures were given and meetings attended by the staff of the Department. So far as possible, all requests of this nature have been met.

An important part of the extension work of the Department is in supervising records of pure-bred cattle, and this work has increased nearly fifty per cent in the year 1913–1914 over the work of the previous year. During the past year official records of 3510 Holstein cows were supervised continuously for seven or more days. These represent about six hundred owners scattered in all parts of the State. In addition, stated monthly inspections of two days each are at present being made for sixty-eight owners, representing the Holstein, Jersey, Guernsey, and Ayrshire breeds. At the present time the records of 623 cows are being supervised in this way, distributed among the various breeds according to the following table:

Breed	Number cows
Ayrshire	148
Guernsey	97
Holstein	96
Jersey	282
Total	623

H. H. WING,
Professor of Animal Husbandry.

DEPARTMENT OF POULTRY HUSBANDRY

It has been the effort of the Department to develop equally the teaching, investigation, extension, and administrative activities of the Department.

TEACHING

In the first table is shown the number of university hours taught each year since the Department of Poultry Husbandry was established in 1903. There has been an almost uninterrupted increase in the number of students taught and the number of hours of instruction given, until the year 1913–1914. The table covers the period from 1903 to 1914, inclusive.

	1903–1904	1904–1905	1905–1906	1906–1907	1907–1908	1908–1909	1909–1910	1910–1911	1911–1912	1912–1913	1913–1914
Regular and special courses	74	339	158	474	527	589	329	620	915	1,413	840
Winter Course in Poultry Husbandry . .	. .	225	540	690	690	780	825	810	825	1,431	688
Winter courses, elective.	54	60	80	64	66	62	66	108	120	128	359
Summer school..			.			. .	.	.	33	154	64
Total	128	624	778	1,228	1,283	1,431	1,220	1,538	1,893	3,126	1,951

The number of students taught in each course for the years 1911–1912, 1912–1913, and 1913–1914 is shown in the following table:

	1911–1912	1912–1913	1913–1914
Regular and special students	183	375	330
Winter Course in Poultry Husbandry..	56	99	41
Winter courses, elective.	60	64	128
Summer school	50	62	43
Total number of students taking one or more courses in poultry husbandry	349	600	542

The abnormal increase in number of students in 1912–1913 is to be accounted for by the fact that certain courses could be given for the first time that year, and students could be accepted, because the Department was able to occupy the new Poultry Building. The decrease in number of students registered in 1913-1914 is due to the establishment of prerequisite work in the regular courses, and to the requiring for the first time of at least six months experience on a successful poultry farm for admission to the winter courses.

INVESTIGATION

The investigations during the last fiscal year, the persons in charge of them, and the number of fowls used, were as follows:

Experiment	Person in charge	Number of fowls		
		Females	Males	Total
Sex inheritance of constitutional vigor (2 flocks)	O. B. Kent	68	10	78
Inheritance of egg production (7 flocks)	J. E. Rice. . .	435	60	495
Influence of methods of feeding breeders on the quality of the offspring (2 flocks)	J. E. Rice . .	45	. .	45
Close winter confinement versus range as influencing egg production, fertility and hatching power of eggs, and the like (4 flocks).	J. E. Rice . .	110	12	122
A study of variations in and inheritance of size, shape, and color of eggs (2 flocks)	E. W. Benjamin.	227	100	327
Natural versus artificial incubation as influencing production, fertility, hatching power of eggs, constitutional vigor, and economical production (4 flocks). .	J. E. Rice. . . .	135	12	147
A comparison of cockerels and capons as influenced by breed, method of feeding, and time of marketing (3 flocks)	J. E. Rice, E. W. Benjamin, O. B. Kent, and W. S. Marsland (graduate student). . Cockerels	. . . .	45	45
	Capons	. . . . . .	45	45
A study of the reproductive system of the domestic fowl as influenced by age, broodiness, constitutional vigor, and the like.	J. E. Rice, O. B. Kent, and R. H. Wilkins (graduate student).	36	. . . . .	36
A study of copulative power and preferential mating in the domestic fowl (1 flock)	J. E. Rice, O. B. Kent, and R. H. Wilkins (graduate student)	80	20	100
A study of the bacteriological content of eggs	E. W. Benjamin and M. L. Thatcher (senior)	. . . . . .	. . . .	. . . .
A comparison of methods of cleaning eggs as affecting their keeping quality	E. W. Benjamin and E. C. Heinsohn (senior)	. . . . . .	. . . . . .	. . . .

Experiment	Person in charge	Number of fowls		
		Females	Males	Total
A study of the quality of eggs handled by the Poultry Producers' Association of Ithaca	E. W. Benjamin and W. S. Young (senior)	.....	.	......
Total ...	....	1,136	304	1,440
Total number of capons	...	.	45	

All the fowls on the experiment plant were trap-nested. An exact record was kept of the food consumed, which was figured in periods of seven days each. Fowls were weighed once each month. All the fowls in breeding projects were stud-mated, and the chicks were pedigreed, leg-banded, and weighed several times during the season. During the year 1912–1913 there were 11 projects under investigation, involving 847 fowls, as compared to 12 projects involving 1340 fowls the past year. A rough estimate of the amount of money involved in the experimental work is shown in the following summary.

The experimenting division occupies jointly with the teaching, administration, and extension divisions the main Poultry Building, costing approximately $110,000 (including fixed equipment, elevators, electric lights, linoleum, refrigeration, and so on); and it uses exclusively:

Poultry houses	$3,045.00	
Stock	1,312.00	
Equipment	1,316.64	
Total investment		$5,673.64
Labor (estimated) (foreman experiment flocks, two assistants and day help, accountant)	$3,000.00	
Maintenance (estimated) (feed, litter, and so forth)	1,500.00	
Total labor and maintenance		$4,500.00
Total investment, labor, maintenance		$10,173.64

It is the policy of the Department to have every person in the departmental staff, including instructors, carry an experimental project as a stimu-

lus to original thought and in order to give the opportunity for discovery of new facts.

One bulletin has been published during the year by this Department — *A Continued Study of Constitutional Vigor in Poultry*, by C. A. Rogers. This is Bulletin 345 of the Experiment Station series.

EXTENSION

In the following table is shown the number and kinds of extension activities of the Department for the year. All told, 584 engagements have been made, which is an increase of 151 over the preceding year.

	1909–1910	1910–1911	1911–1912	1912–1913	1913–1914
Farm visits to assist in selecting breeding stock, grading eggs, laying out plans for poultry farms, and the like.	17	62	180	255	316
Speaking engagements in connection with poultry shows, granges, Young Men's Christian Associations, farmers' institutes, extension schools, farm trains, fairs, and the like...	109	79	92	136	185
Educational exhibits staged in connection with poultry shows, agricultural fairs, Young Men's Christian Associations, farm trains, extension schools, and the like..............	18	23	34	42	83
Total	144	164	306	433	584

The nature of the extension activities and the persons who represented the Department in this work are shown in the following tables. It has been the policy of the Department to encourage nearly all members of the staff to do some extension work during the year. Two persons, Messrs. Krum and Moseley, have given all their time to extension work, and Mr. Hurd has given his time during the four months of greatest extension activity.

This table shows the number of educational exhibits prepared by the Department during the year, and the representative of the Department sent out with the exhibit:

Name of representative	Poultry shows		Extension schools		Farm trains		Fairs		Young Men's Christian Association		Farmers' institutes	
	Places	Number of days	Places	Number of days	Places	Number of days	Places	Number of days	Places	Number of days	Places	Number of days
W. G. Krum ...	6	32	4	21			2	10			1	1
L. M. Hurd. .	1	5	8	46					1	6		
R. S. Moseley...	7	34	2	10	40	18	6	22				
T. E. Schreiner ..	1	1										
F. W. Kazmeier. .							1	4				
A. B. Dann.. ..							2	11				
Total . .	15	75	14	77	40	18	11	47	1	6	1	1

Total number of places visited.. 82
Total number of days. 224

This table shows the number of lectures given by members of the departmental staff on subjects having to do with poultry husbandry:

Name of representative	Rural schools		Extension schools		Farm trains		Farmers' institutes		Granges		Young Men's Christian Association		Poultry shows		Special lectures	
	Places	Number of lectures	Places	Number of lectures	Places	Number of lectures	Places	Number of lectures	Places	Number of lectures	Places	Number of lectures	Places	Number of lectures	Places	Number of lectures
J. E. Rice							1	2	2	3	1	1			5	5
E. W. Benjamin									1	1					4	4
W. G. Krum	70	70	4	32			1	2	10	15			6	26	13	25
L. M. Hurd			10	68			1	1			1	7	1	1		
R. S. Moseley	7	7	3	15	3	3	3	4	2	2	1	2	7	39	14	22
T. E. Schreiner							2	4					1	3	4	7
F. W. Kazmeier									1	1	1	2	1	1	3	4
A. B. Dann															1	3
Total	77	77	17	115	3	3	8	13	16	22	4	12	16	70	44	70

Total number of places visited. 185
Total number of lectures. . . 382

This table shows the number of farm visits made during the year by representatives of this Department:

Name of representative	General visits		To boys and girls		Farm survey		State institutions		Market survey		Excursions	
	Localities	Farms	Localities	Farms	Localities	Farms	Localities	Farms	Localities	Farms	Localities	Farms
E. W. Benjamin									1	20	1	20
C. A. Rogers...	5	5									4	4
W. G. Krum . .	32	68	10	20			5	7				
L. M. Hurd .	15	41										
R. S. Moseley .	32	113										
T. E. Schreiner..	3	6									7	9
F. W. Kazmeier.	1	1										
A. B. Dann.. .	1	2										
Total	89	236	10	20			5	7	1	20	12	33

Total number of localities visited..... . 117
Total number of farms visited.. 316

SUMMARY STATEMENT

Name of representative	Attendance at lectures	Number of breeding stock selected	Expense				
			United States Department of Agriculture	Department of Extension Teaching	Department of Poultry Husbandry	Private parties or associations	Total expense
J. E. Rice	1,528	....	$ 12 54	$ 16 92	$ 12 29	$ 29 01	$ 70 76
E. W. Benjamin	770	....	....	8 24	16 72	6 15	31 11
C. A. Rogers	....	....	....	..	16.67	22 00	38 67
W. G. Krum	12,153	9,459	78 27	152.06	100 17	187 84	518 34
L. M. Hurd	3,010	..	6 15	218 92	31 26	56 68	313 01
R. S. Moseley	13,023	18,537	27 78	243 87	128 06	354 03	753 74
T. E. Schreiner	556	1,675	....	..	30 28	44 80	75 08
F. W. Kazmeier	1,090	50	..	38.66	....	4.72	43 38
A. B. Dann	135	40	......	55 85	..	....	55 85
O. B. Kent	....	....	...	15 95	..	....	15 95
Total	32,265	29,761	$124 74	$750 47	$335 45	$705 23	$1,915 89

Total attendance at lectures	32,265	
Total number of breeding stock selected	29,761	
Expense:		
United States Department of Agriculture	$ 124.74	— 6 5 per cent
Department of Extension Teaching	750.47	— 39 2 per cent
Department of Poultry Husbandry	335.45	— 17 5 per cent
Private parties or associations	705 23	— 36 8 per cent
Total expense	$1,915 89	

The total number of persons reached in the lectures was 32,265. The amount of breeding stock selected was 29,761. In meeting the various extension engagements 213 towns were visited. The total expense involved in all extension activities outside of salaries amounted to $1915.89, only $335.45 of which was paid from funds appropriated to the Department of Poultry Husbandry. Of the total expense 6.5 per cent was paid by the United States Department of Agriculture, 39.2 per cent by the Department of Extension Teaching, 36.8 per cent by private parties or associations, and 17.5 per cent by the Department of Poultry Husbandry.

The following table is a financial summary of the estimated expense of carrying on the various extension projects, A to I, respectively.

Number of project	Poultry state fund			Poultry extension fund			Total all funds
	Salaries	Maintenance	Total salaries and maintenance	Salaries	Maintenance	Total salaries and maintenance	
A	$ 633 33	.....	$ 633 33	$ 958 33	$596 00	$1,554.33	$2,187 66
B	366 67	. .	366 67	83 33		83 33	450.00
C	1,083 34	$300.00	1,383 34	504.00	100 00	604 00	1,987 34
D	366 66	. ....	366 66	458 34		458 34	825 00
E	800.00	....	800 00	.	. .	. ..	800 00
F	50.00	. ..	50 00	. ..	100 00	100 00	150.00
G	100 00	.....	100 00	..	100 00	100 00	200 00
H	400.00	.. ..	400 00	..	100 00	100.00	500 00
I	208 00	.	208 00	.			208 00
Total	$4,008.00	$300 00	$4,308.00	$2,004.00	$996 00	$3,000.00	$7,308 00

This shows that $4308 of state maintenance funds was used for extension projects as compared to $3000 appropriated especially for extension work, and that the total amount of money expended for extension activities was $7308. The extension projects of the Department of Poultry Husbandry are briefly reviewed as follows:

CORRESPONDENCE

The following table shows the amount of correspondence for the years 1908–1909 to 1913–1914, respectively:

	1908–1909	1909–1910	1910–1911	1911–1912	1912–1913	1913–1914
Letters	7,088	7,470	7,364	8,456	9,304	9,084
Form letters	......	......	2,393	2,141	2,198	1,580
Total	7,088	7,470	9,757	10,597	11,502	10,664

Poultry survey.— The following table gives the results of the poultry farm postal-card survey. Results for all the years to and including 1912–1913 are given, and results for the year 1913–1914:

Number of fowls	Number of farms 1912–1913	Number of farms 1913–1914
1 to 200	583	918
201 to 500	238	354
501 to 1000	100	134
1001 to 2000	35	47
2001 or more	16	17
Total	972	1,470

The postal-card survey is an exceedingly valuable means of enabling the Department to keep in touch with the most active poultrymen of the State, and thus to meet many others.

The cooperative marketing association. — An itemized statement is being prepared by Professor Benjamin, showing the results of an endeavor to assist in the organization and management of the Poultry Producers' Association of Ithaca. This will form the subject of a special report to be submitted at an early date. Up to the present time the administration of the Poultry Producers' Association has been in the Poultry Building, under the direct supervision of the Department of Poultry Husbandry. Steps are now being taken to establish the association on an independent basis in the city of Ithaca, in cooperation with the Tompkins County Farm Bureau, the Tompkins County Breeders' Association, granges, and various civic organizations.

The rural school work.—Mr. Krum has devoted considerable time to this educational project, in cooperation with other agencies in Chemung and Tompkins Counties. Some of the results of this work are shown in the statement prepared by Mr. Krum, which is incorporated in the following table. Henceforth this work is to be carried on conjointly with the Department of Rural Education.

The following is a report of poultry extension work done in the rural schools in March and April, 1914, by W. G. Krum, in cooperation with business men's associations, farm bureaus, granges, school superintendents, and fair associations.

Tompkins County

Number of lectures	21
Number of pupils attending	1,193
Number of pupils furnished settings of eggs	262
Number of pupils reporting	187
Number of pupils raising eight or more chicks	114
Number of pupils raising thirteen chicks (included in above)	25
Number of pupils showing chicks at county fair	31
Value of premiums won	$33
Money donated by Business Men's Association	$141
Number of settings of eggs purchased	133
Number of settings of eggs donated by breeders	40
Number of settings of eggs donated by Department of Poultry Husbandry	89

Chemung County

Number of lectures	27
Number of pupils attending	2,130
Number of pupils furnished settings of eggs	478
Money donated by Elmira Business Men's Association	$400

Poultry institute.— Each year since the establishment of the Department of Poultry Husbandry, a poultry institute has been held during Farmers' Week, at which time an educational exhibit and a poultry show have been held whenever a place has been available for the exhibition. Last year the experiment was tried of giving visitors an opportunity to get contact experience in laboratory and practice types of instruction. This feature of Farmers' Week was well patronized and was successful from an educational standpoint. The attendance at various exercises in the Poultry Building during Farmers' Week for the years 1912–1913 and 1913–1914 is shown in the following tables:

	1912–1913	1913–1914
Demonstrations	....	425
Lectures	4,817*	4,078
Laboratory periods	315	226
Contests	170	15
	5,302	4,744

*In 1912-1913 the attendance includes that at the dedication exercises of the Poultry Building.

The following table shows the attendance at the Poultry Building during Farmers' Week by days, 1913–1914:

Monday	850
Tuesday	1,296
Wednesday	832
Thursday	598
Friday	1,168
Registered attendance at poultry show	708
Total attendance	5,452

A poultry survey of the city of Ithaca.— Mr. O. B. Kent is preparing a bulletin for publication dealing with the results of his poultry survey of the city of Ithaca. In this survey account has been taken of the poultry consumed and produced, and the source of supply for the city. Dr. Benjamin has now taken over this project, and intends to make a similar survey in a suitable town in this vicinity. By this survey it is hoped to obtain valuable information in regard to the cost of distributing poultry products, as well as cost of production and methods of care. This work is done with the hope that the College may be of material assistance to the producer, the distributor, and the consumer.

Breed-testing project.— Two years ago the Department inaugurated a breed-testing project, which was discontinued after the first year so far as receiving birds from outside breeders was concerned, because of lack of facilities due to the removal of the old plant from the campus to the farm near Forest Home. The project was resumed this year in a limited way. This project has for its prime purpose the systematic breeding of birds with a view to increasing the quantity and quality of eggs. An effort has been made to eliminate practically all the publicity features of a contest, in order to concentrate effort more effectively on the main purpose, which is to establish systematic line-breeding on as many farms as possible in the State. It is proposed to mate the best line-bred birds with the choicest individuals sent here for the breed test. This project is worthy of extensive development. It will require considerable expenditure for buildings. It will be largely self-sustaining, from the sale of eggs and from the entrance fee of $10.

Cornell extension schools.— The Department is planning to systematize the teaching of poultry husbandry in connection with the extension schools, by the use of printed lectures and laboratory exercises that are to be taken up in a logical sequence with the view of having the work cover an extension school about two or three years in succession. This unquestionably is a logical step in the development of the farmers' institute movement.

Because of the large demand on the part of poultry associations during the extension school season, it will be necessary for the Department to have additional help another year if it is to meet the demands for educational exhibits, lectures, demonstrations, and the like, from November 1 until March 1.

Farm visits.— More and more it is becoming apparent that some of our most effective work is in the following-up of the work of our extension schools, poultry show engagements, and the like, by farm visits in order to study problems first-hand, to assist in laying out poultry farms, recommending reconstruction of buildings, compounding rations, selecting stock, and the like. Inasmuch as this type of work is entirely self-sustaining, so far as maintenance is concerned, the College can well afford to employ whatever help may be necessary to meet the demands.

Educational exhibits.— Each year since the Department was established in 1903–1904, educational exhibits have been staged in connection with the poultry institute and poultry show at Cornell University and with various organizations in the State By the use of models, photographic enlargements, live and dressed poultry, eggs, and the like, it is possible to teach visually what could not be taught successfully by verbal means.

The Department now has three well-equipped educational exhibits, made essentially in triplicate. Nearly every week from early in September until early in March, one or all of these exhibits are in active use, and for approximately three months of this time two or three of them are engaged. There is need this winter for a fourth exhibit if the demands of the public are to be met.

ADMINISTRATION

The amount of stock on the poultry farm for the years 1908 to 1914, inclusive, is shown in the following table:

	1908	1909	1910	1911	1912	1913	1914
Old.	829	739	1,045	1,495	1,561	2,498	2,583
Young.	3,298	3,683	2,803	3,031	3,502	5,320	5,000
Total	4,127	4,422	3,848	4,526	5,063	7,818	7,583

The material, facilities, and equipment of the Department are shown in the following table, which includes the inventory and valuation of the land, buildings, stock, and equipment, from July 1, 1908, to July 1, 1914:

	1908	1909	1910	1911	1912	1913	1914
Land..........	$ 1,000	$ 1,000	$ 3,500	$ 3,500	$ 3,500	$ 7,100	$ 7,775
Buildings.......	5,876	6,248	6,416	6,438	7,225	102,850	104,089
Stock...........	2,696	2,034	3,400	3,098	4,264	4,795	4,134
Equipment.......	3,569	4,876	6,496	6,975	7,471	13,580	18,083
Total.........	$13,141	$14,158	$19,812	$20,011	$22,460	$128,325	$134,081

The total valuation will be materially increased this year in the construction of outdoor laboratory buildings costing $25,000. These include a main feed building, two stories and basement; a fattening building, two stories with pigeon loft; an exhibition building, two stories; four series of laying pens; and one or more pipe-system brooder houses.

JAMES E. RICE,
Professor of Poultry Husbandry.

DEPARTMENT OF RURAL ENGINEERING

TEACHING

Rural engineering consists of three main divisions — farm engineering, farm mechanics, and farm structures. Coincident with the change of name of the Department, the course in farm structures formerly given by the Department of Farm Practice was offered by this Department, so that work is now given by this Department in all the main branches of rural engineering. The course in drainage and irrigation formerly offered by the Department of Soil Technology was this year given as one of the courses in farm engineering, the Department of Soil Technology cooperating. The three elementary courses of the Department were given during the new third, or summer, term. The winter course in farm engineering was discontinued because it could not well be given at that season of the year.

The teaching in farm engineering and in farm structures was greatly hampered because of lack of adequate drafting-room facilities. Most of the work was given in an ill-ventilated attic of the Dairy Building, which, during the winter, was used five afternoons each week. This arrangement left other students without quarters, so that the remainder of the drafting was done on the arms of the seats in vacant lecture rooms or in the already congested offices of the Department. Such conditions are discouraging to both student and teacher.

The total number of students registering in the Department was 532, as against 707 enrolled the previous year. Part of this decrease is due to the discontinuance of one winter course, part to the radical rearrangement of the college curriculum as a whole, and part to the inadequate drafting facilities above referred to. Many students deferred registration with the Department in the hope that better quarters would soon be forthcoming.

INVESTIGATION

Because of the increased teaching work, the staff of the Department had little opportunity for research. Work was begun on the compilation of data as to types of barn frame construction and the classification of barn roof trusses. An experimental irrigation pumping-plant was designed and installed for the Department of Vegetable Gardening.

EXTENSION

Most of the direct extension work of the Department has been in the field of farm engineering, in which ten surveys and reports, four maps, and two profiles were prepared, and one lecture was delivered. Twenty trips were made in all. Cooperation in this work with the farm bureau managers promises to largely increase the amount of effective work done on each trip.

The Reading-Course lesson on sewage disposal for country homes, under preparation last year, was completed, and special models illustrating some of the designs were made by the staff and exhibited at the State Fair and at the annual meeting of the health officers of the State. The lesson has been reprinted by the State of Pennsylvania for general distribution. Instruction in sanitation was given at two extension schools and at five lectures.

In farm structures, several sets of plans for farm buildings were prepared and sent out, one set covering an entirely new group of strictly modern buildings.

During the year the Department used a considerable part of its regular appropriation in an attempt to develop a satisfactory extension teacher; but its efforts were unsuccessful, as it is not easy to find a man with the necessary technical training, actual farm experience, good judgment, and teaching ability of the type required for extension work.

RECOMMENDATIONS

The most urgent need of the Department is for better drafting-room facilities, and also for additional offices near the drafting rooms which would materially increase the efficiency of the staff.

No training in shop work is now given directly by this Department, and this is to be regretted. Agricultural students may take forge work in the Sibley College shops, but no suitable course in woodworking is available there for them. Through the cordial readiness of the Faculty of Sibley College to cooperate with the Faculty of the College of Agriculture, it would be possible, if funds of this Department were available, to place instructors in the Sibley shops in order to give courses in woodworking and in forge. These courses would be classed as agricultural electives and would be especially adapted to the needs of agricultural students. Many of the students of our College are to become teachers in the agricultural schools of the State, in which the State Department of Education is emphasizing the work in manual training and is requiring that the teachers be skilled in the subject. It is urgently recommended that funds be made available at the earliest opportunity for two instructors in manual training.

The Department is much in need of funds for research work. This would be carried on as laboratory and field work at the College, and also as field surveys of existing conditions throughout the State. In all three branches of the work of the Department, this need of direct and constant touch with actual conditions is keenly felt, and it is hoped that next year funds for this purpose will be available.

HOWARD W. RILEY,
Professor of Rural Engineering.

DEPARTMENT OF AGRICULTURAL CHEMISTRY

TEACHING

During the college year, 727 students received instruction in ten courses. Seventy-one students were enrolled in the summer school in four courses of instruction. In addition, a course of lectures was given to 292 winter-course students.

INVESTIGATION

The amount of investigation done by this Department has necessarily been small. One of the professors of the staff was absent for one semester, on sabbatic leave. The time of the members of the staff was practically all taken up by instruction and by extension work. One investigation, " Studies on Erepsin," was carried on by Mr. Rice.

EXTENSION

The extension activities of this Department are confined to two lines:

1. The chemical examination of samples of various agricultural products that are submitted by people of the State. During the past year 480 samples were examined. These may be grouped as follows:

Soils	206
Limestone	119
Vinegar	16
Fertilizers	48
Feeds	36
Foods	10
Water	5
Insecticides	7
Sugar beets	8
Rock	11
Ashes	6
Miscellaneous	8

2. Lectures before granges, extension schools, and farmers' organizations have been given by Professors Cavanaugh and Cross. Mr. Rice, the instructor in the Department, was in attendance during six weeks at the State and county fairs, with an educational exhibit from this Department.

GEORGE W. CAVANAUGH,
Professor of Agricultural Chemistry.

DEPARTMENT OF LANDSCAPE ART

It was the purpose of the administrative office of the College to have finished at the beginning of the year 1913–1914 a small building that would completely house the Department of Landscape Art. This work was delayed and was not begun until late in the fall. The building mentioned was the old workshop of the Department of Poultry Husbandry, which was then on the site of the new Soils Building. Need of space for administrative purposes on the first floor of the main building made it necessary for the Department to go elsewhere for its drafting-room space, and so it began the year 1913–1914 under disturbed conditions. Late in November the work of moving and altering the present Landscape Art Building was begun, and the building was partly occupied after the winter recess and entirely occupied by the close of the first term.

TEACHING

While the conditions under which the Department began the year were not encouraging to an increase of students, there was a considerable addition to the enrollment of the previous year, and this principally in the courses open to general election. It is the purpose of this Department to emphasize its courses open to general election, and, further, to add each year to the number of these open courses. The new courses under consideration are those in propagation, which were requested by some of the other departments since we are developing the arboretum; and courses in the arrangement and design of small gardens, using and requiring as prerequisites courses already given by the Department of Floriculture.

INVESTIGATION

The disturbed conditions under which the Department has had to work in the past year, together with an almost total lack of office assistance, has prevented any considerable amount of study or investigation. There has been a demand for several publications evinced by requests for information received in the daily mail. One bulletin will be published during the coming year, and two others will be undertaken.

Opportunity for a considerable amount of study should be given to the instructing staff, for the reason that the teaching of landscape work in any of its phases is comparatively new. The better facilities and organization of the Department in its present quarters will alleviate, to a considerable extent, the difficulties in the way of such investigation.

EXTENSION

During the year there has been considerable demand for extension work, from state institutions and village improvement societies especially, and there has been an increase in the amount accomplished as compared with the preceding year. The Department is in need of an extension officer to meet the requirements of village and school-ground improvement.

Work with individual properties has been given little time, in spite of a steady call for assistance. The betterment of the residence and home surroundings is a vital matter. One or two half-days are set apart in Farmers' Week for the answering of questions and the giving of assistance in diagrams to individuals who bring sketch plans of their homes and farms. This work, however, is not far-reaching. The home and the village, with all that is becoming a setting for our New York State country life, whether it be water edge of the new canal, railroad station, or village green with its old tavern and stores — all this environment needs to be given every possible opportunity, not only to regain a former attractiveness, but also to be adapted to the new thrift and commercial conditions of life in the country to-day. This work can be cared for when assistance is provided in the Department.

The Department continues to be in charge of the improvements on the campus of the College of Agriculture. These duties have been very heavy in the past; but now that the general plans have been settled upon and the heaviest work has been done in the execution of these plans, the remainder becomes a matter of detail.

RECOMMENDATIONS

Additional teaching staff is needed, in order to teach properly the several lines of study included in the departmental courses and to offer some additional courses, broadening the scope of the Department. Additional staff is sorely needed also to care properly for the extension work and the extension opportunity of this Department in the State. Some assistance is needed in order to enable the Department to respond more quickly to requests of other departments for improvements around their buildings and working lands. The Landscape Art Building needs to have completed its library, its men's lavatory, and its exhibition room. These rooms are already finished with the exception of their interior trim. The lavatory plumbing is all on hand, to be set up.

BRYANT FLEMING,
Professor of Landscape Art.

DEPARTMENT OF DRAWING

TEACHING

For the past year the number of students registered in the several courses in the Department of Drawing was as follows:

Course	Subject	Number of students registered	
		First term	Second term
1	Mechanical Drawing	38	49
2	Free-hand Drawing	30	21
3	Applied Drawing	12	17
4	Perspective	13	17
		93	104

To the student of agriculture, whose life work requires an ever-increasing familiarity with farm structures and farm machinery, the practical value of a short general course in mechanical drawing is obvious. The great majority of graduates of any college of agriculture should have sufficient training to enable them to read building plans and simple machine drawings. The disciplinary value of such a course is too well understood to require demonstration.

It was in order to meet the needs of the general agricultural student that the course in mechanical drawing was established a few years ago; but already new demands have arisen, and the course in the latter half of the term must now be adapted, for a part of the class, to the different requirements of students in the Department of Forestry. In drawing, the needs of the students of forestry are not very unlike those of the civil engineers, who devote much more of their time to this subject. Doubtless, before long a special enlarged course must be established for students of forestry.

In another branch of mathematical drawing, perspective, this Department now provides instruction that was previously given in the College of Architecture. Because of lack of accommodations in that College, this Department was asked to give the necessary instruction in perspective. The prerequisite for this course, descriptive geometry, is still

taken in the College of Architecture by the students of landscape art; but in a year or two students will doubtless be crowded out of this course. This Department is preparing to meet the situation when it arises, and Mr. Reyna, the instructor now in charge of the mechanical drawing, is thoroughly equipped to give instruction in any and all branches of mathematical drawing that may be required by any students or class of students in the College of Agriculture.

INVESTIGATION

The Department of Drawing does no investigative work as such, yet constant experiments are being made in order to determine the best materials and methods for graphic expression required by scientific students.

EXTENSION

While this Department engages directly in no extension work, it has the drawing and overseeing of most of the illustrations for bulletins, Reading-Course lessons, and Rural School Leaflets. By making these illustrations as artistic as is consistent with accuracy, an indirect æsthetic influence is exercised on the taste of the readers of these publications.

RECOMMENDATIONS

Any recommendations that the Department might wish to make would be in the nature of added appropriations. More funds could well be spent for demonstration apparatus and machine parts for use by the classes in mechanical drawing, and large casts and botanical models for the courses in free-hand. Additional funds could also be used in purchasing facsimile reproductions of good paintings, suitably framed, for aiding in the development of the students' appreciation of fine art.

W. C. BAKER,
Professor of Drawing.

DEPARTMENT OF RURAL ECONOMY

TEACHING

No changes were made in the program of instruction for the regular academic year. All courses continue to increase in the number of students. This year, for the first time, the Department offered courses in the summer school. Another line of endeavor is that of the School for Leadership in Country Life. The fourth session of this school was very successful, having 62 registrations from 14 States and foreign countries. In particular the exhibit side of the school was very much more developed than in previous years, due in no small part to the aid of many outside agencies.

INVESTIGATION

Investigation other than for developing facts for class use has been confined to the study of food production in the United States. Some of the data have been charted and are therefore available for class use.

EXTENSION

Extension work has been continued primarily along the line of investigating the history and present status of cooperation within the State of New York. While it was not possible to get an assistant to carry out the actual survey, the future progress of this work lies in the gathering of survey data and putting them in presentable condition. A number of meetings and conventions were attended, primarily in the interest of the development of cooperation in the State; this is true also of the calls made by the Governor of the State.

In Farmers' Week an entire day was given up to the rural church problem from both sides — that of the layman and that of the pastor. This was the most successful meeting, from the standpoint of numbers as well as of spirit, that Farmers' Week has seen.

G. N. LAUMAN,
Professor of Rural Economy.

DEPARTMENT OF RURAL EDUCATION

TEACHING

The teaching of this Department during the past year has been limited to the following courses, which were offered during the summer school:

The School.—This course suggested methods of instruction in elementary agriculture and nature study, taking as a basis the work outlined in the New York State Syllabus for 1914–1915. Simple apparatus used in teaching country-life subjects was shown and discussed. Other subjects of lectures and discussions were as follows: gardening in education; field work; natural history collections; neighborhood studies; the school and the home; recreation in country districts; dramatic entertainments; agricultural contests; the county fair; small school exhibits; additions to the school library; the school grounds; Arbor Day; Corn Day; and similar topics of interest to grade teachers, training-class teachers, district superintendents, and all persons interested in introducing country-life subjects into schools.

Methods of Teaching High School Agriculture.— This course was intended for teachers who had had some technical agriculture and desired help in methods of presentation.

INVESTIGATION

This is a field that is as yet practically untouched, except for such investigations as have been incidental to other phases of work in the Department.

EXTENSION

The aims of the extension work of the Department have been fully set forth in former reports and need not be repeated here.

The work of the past year, 1913–1914, was as follows:

Publications

The means of communication between the Rural Education Department and the schools of the State is the Cornell Rural School Leaflet. In 1913–1914 the leaflet was issued as follows:

1. The September, 1913, number for teachers covered the year's work for 1913–1914 as outlined by the State Syllabus. The edition was 55,000 copies. On June 1, 1914, 49,709 copies had been distributed. All rural teachers and training-school pupils were supplied, and about eighty per cent of the city and village grade teachers.

2. The November leaflet for boys and girls comprised twenty-eight pages. The edition was 200,000 copies.

3. The January leaflet for boys and girls comprised twenty-eight pages. The edition was 200,000 copies.

4. The March leaflet for boys and girls comprised forty-eight pages. The edition was 200,000 copies.

5. In April a special number of the leaflet was issued on *Decoration for the Rural School*. This leaflet was prepared by Mr. Royal B. Farnum, of the University of the State of New York, and comprised forty pages, with three colored illustrations and numerous illustrations in black and white. The edition of 20,000 copies was distributed to teachers in rural schools. A small supply is still available for individual requests. This leaflet has found favor in all parts of the country, and has been widely commented upon.

6. The September, 1914, leaflet. Prior to October 1, 1914, the new teachers' leaflet for 1914–1915 had already been compiled, and 42,757 copies out of an issue of 55,000 had been distributed. The leaflet comprised two hundred and seventy-six pages. It covered the topics in nature study and elementary agriculture for study in the rural schools during the coming year as outlined by the State Syllabus.

7. The editors of the Cornell Rural School Leaflet organized and prepared the May number of the Reading-Course Lesson for the Farm, entitled *The Rural School and the Community*. This lesson has been sent to all rural teachers, in addition to the regular Reading-Course mailing list.

Copies of all these publications accompany this report and will be found in Part II. Detailed descriptions of them are therefore omitted here.

Correspondence

During the year, 18,610 pieces of first-class mail were received at the office, and 10,677 pieces were sent out, including about 3000 circular letters. Next to the publication of the leaflet, correspondence is the most important function of the extension staff, and the necessity for personal attention in a larger percentage of the letters received is increasing each year.

Children's letters.— During the year, 11,261 letters were received from boys and girls in rural schools of the State. These were all carefully read, technical questions were answered, and the letters were recorded. A small gift picture was sent to each child from whom three letters were received; 1798 children wrote the three letters. No attempt is made to push the correspondence with children, since it would be impossible to properly take care of it with the present staff.

Meetings attended

The following table shows the meetings attended by members of the departmental staff in the year 1913–1914:

Place	Date	Kind of meeting	Speaker	Number of persons in attendance
	1913			
Wellsville	October 1, 2, 3	Teachers of Allegany County	Miss McCloskey	350
Fonda	October 16	Teachers of Montgomery County	Miss McCloskey	200
Ithaca	October 24, 25	District Superintendents of Central New York.	Miss McCloskey	30
Elmira	October 31	Teachers of Chemung County	Miss McCloskey	150
Sherwood	November 22	Grange and School Day	Mr. Tuttle	350
Syracuse	November 24, 25, 26	New York State Teachers Association	Miss McCloskey	700
Mexico	December 1, 2	Grangers and teachers of Oswego County	Miss McCloskey	500
Binghamton	December 19.	Teachers of Broome County.	Miss McCloskey	350
	1914			
New York	February 17–20	District Superintendents	Mr. Tuttle (attended but did not speak)	200
Addison	April 3	Teachers of Steuben County, Districts 1, 3, 4, 5	Miss McCloskey	500
Cortland	April 14	Twentieth Century Club	Miss McCloskey	200
Danby	April 18.	Teachers of Town of Danby	Mr. Tuttle	15
Norwich	April 24.	Teachers of Chenango County	Miss McCloskey	200
Union Springs	April 27	Union High School	Mr. Tuttle	100
Watertown	May 1, 2	Teachers of Jefferson County	Miss McCloskey	400
Slaterville Springs	May 8	Teachers of Town of Caroline	Mr. Tuttle	20
Interlaken	May 11	Teachers, District 1, Seneca County	Miss McCloskey and Mr. Tuttle	75
Trumansburg	May 15	Teachers, Town of Ulysses	Mr. Tuttle	25
Newfield	May 25	Teachers, Town of Newfield	Mr. Tuttle	20
Fair Haven	May 29	Teachers, District 1, Cayuga County	Mr. Tuttle	75
Marilla	June 19	Field Day, Town of Marilla	Mr. Tuttle	400
Rushford	September 16, 17, 18	Teachers, District 1, Allegany County	Miss McCloskey	400
Danby, District 10	September 23	School fair	Miss McCloskey and Mr. Works	50
Unadilla	September 23	School fair	Mr. Tuttle	500
Otego	September 24	School fair	Mr. Tuttle	300
Oneonta Plains	September 26	School fair	Mr. Tuttle	200
Milford	September 27	School fair	Mr. Tuttle	400

The following table shows the number of rural schools visited by Mr. Tuttle in the year 1913–1914:

Date	Number of district	Town	County
1913			
October 1	12	Cortland	Cortland
October 1	13	Cortland	Cortland
October 2	3	Solon	Cortland
October 3	2	Freetown	Cortland
October 6	8	Cincinnatus	Cortland

Date	Number of district	Town	County
1913			
October 7	4	Cincinnatus	Cortland
October 8	6	Cincinnatus	Cortland
October 9	5	Cincinnatus	Cortland
October 14	2	Willet	Cortland
October 15	1	Willet	Cortland
October 16	5	Smithville	Chenango
October 17	1	Smithville	Chenango
October 20	10	Greene	Chenango
October 21	11	Greene	Chenango
October 21	9	Greene	Chenango
1914			
May 20	1	Seneca	Ontario
May 20	11	Seneca	Ontario
May 21	7	Seneca	Ontario
May 21	13	Seneca	Ontario
May 22	8	Seneca	Ontario
May 22	7	Seneca	Ontario

Farmers' Week

Nine conferences for district superintendents and teachers were held in the model schoolhouse on the campus. At each conference a district superintendent or a prominent educator presided. The topics discussed were: (1) Boys and girls in rural districts; health, work, resources. (2) Present-day preparation of the rural school teacher; of the trustee. (3) The rural school as a social center, its relation to home, church, grange; consolidation; demonstration schools. (4) Rural school ground, land for experimental work in elementary agriculture, school and home gardens. (5) The rural school building, its design, interior decoration, equipment, library. (6) Agriculture in elementary schools, nature study, domestic science. (7) Agricultural contests and exhibits, Corn Day, Farmers' Week. (8) Cooperation between district superintendents, special teachers of agriculture, farm bureau agents, and others. (9) Rural recreation, pageants, folk songs, folk dances, dramatics, and public speaking.

In addition to the conferences, two exhibitions of rural school work were displayed: (1) The school corn show was held in Bailey Hall. Eight hundred and ninety-six rural schools were represented by not more than two ears of corn each. (2) An exhibit of general natural history work from 298 rural schools was set up on the fourth floor of Roberts Hall.

Babcock test outfits

A Babcock test outfit was sent for a limited time to seven schools. One outfit was loaned to a district superintendent, who used it in many schools in his district.

RECOMMENDATIONS

One of the decided handicaps to the development of instructional work in agricultural and home-making subjects in the public schools is the lack of an adequate supply of properly prepared teachers of these subjects. The technical preparation of persons for this work should be broad and of such character as to put them in the right attitude toward its use for educational purposes. The pedagogical preparation should be practical and should supplement the technical preparation in the development of a proper spirit for carrying out the work in the public schools. These two purposes may be accomplished by the specifying of certain technical courses that should be taken by prospective teachers, and by the development of the teaching work of this Department. Provision should be made at the earliest possible date for instructors to assist in the development of this work, as outlined in the financial forecast of this Department.

The College receives a considerable number of calls each year for persons to fill positions of agricultural education in colleges and normal schools. Advanced work of such character as to give students preparing for this work proper preparation, should be developed in the near future.

The College should cooperate with a few rural schools in different parts of the State in assisting them in the development of the work in agriculture, home making, and nature study, for the stimulating influence they may have on other schools.

The Department should develop illustrative material for the teaching of agricultural subjects in both elementary and secondary schools. In addition, there should be brought together good library and laboratory equipment for both types of schools as suggestive to school authorities and teachers of what their schools should possess. Much of this equipment could be used in the extension work of the Department.

GEORGE A. WORKS,
Professor of Rural Education.

DEPARTMENT OF HOME ECONOMICS

The staff of the Department of Home Economics in 1913–1914 comprised the following persons: two heads of department, one assistant professor on full time, two assistant professors on half time, two instructors on full time, one instructor on half time, three student assistants, one extension school assistant on half time, manager of cafeteria, clerk and housekeeper, stenographer, two housekeepers, one janitor.

TEACHING

The growth and development of such branches of the Department as are fully represented has been vigorous and normal. Because of extremely limited funds, new work that was needed was not added. The main effort of the Department has been, therefore, to develop and invigorate work previously begun, and the year's results seem to warrant the belief that the courses now offered by the Department are on a good educational basis.

The classroom work done by members of the Department was approximately as follows:

	First term	Second term	Winter course
Number of courses given	11	12	5
Number of lectures given each week	16	18	10
Number of laboratory periods each week	30	35	11

The approximate number of students registered in the Department was as follows:

Freshmen specializing in home economics	60
Sophomores specializing in home economics	50
Juniors specializing in home economics	40
Seniors specializing in home economics	22
Other regular students taking some work in the Department	90
Winter-course students specializing in home economics	60
Total	322

Practical laboratories for those students interested in the professional phases of home economics were found in the cafeteria, through the public

schools, in night-school classes held in the building, and in the rural schools in the vicinity of Ithaca.

INVESTIGATION

Lack of funds places the Department in a position where it is impossible to develop any work in the field of investigation. It will be impossible to carry on any work in investigation until the undergraduate work in the Department has been amply supported.

EXTENSION

Reading-Course for the Farm Home

The purpose of this course is to carry instruction to farmers and farmers' wives, as well as to others not attending college, through demonstrations, lectures, lessons, and correspondence, with follow-up work in visiting homes, and in the formation of farmers' wives' study clubs organized for more extensive study of subjects in home economics.

Twelve lessons were published during the year, on the following subjects:

49. Household insects and methods of control. Glenn W. Herrick.

51. A story of certain table furnishings. Clara W. Browning and Edith J. Munsell.

53. The Christmas festival. Bertha Betts.

55. Rice and rice cookery. Miriam Birdseye.

57. A syllabus of lessons for extension schools in home economics. Miriam Birdseye.

59. Sewage disposal for country homes. Howard W. Riley.

61. Attic dust and treasures. Blanche E. Hazard.

63. The young woman on the farm. Martha Foote Crow.

65. Farmhouse amusements for girls and boys. Blanche E. Hazard.

67. Canning clubs in New York State.— Part I. Organization. Martha Van Rensselaer.

69. Canning clubs in New York State.— Part II. Principles and methods of canning. Flora Rose and O. H. Benson.

71. Canning clubs in New York State.— Part III. Canning equipment. O. H. Benson and Flora Rose.

Number of readers October 1, 1913	28,446
Number of readers September 30, 1914	37,732
Number of clubs October 1, 1913	70
Number of clubs September 30, 1914	93
Number of meetings attended	139
Number of addresses given	151
Number of letters written	3,171
Number of circulars sent	961

Extension schools in home economics

The purpose of the extension schools is to carry instruction in home economics by means of five-days schools, of one or two sessions each day, to residents of New York State not attending college. These schools are held in connection with extension schools in agriculture and on the same dates; or, in communities not desiring agricultural instruction, they are held separately.

Number of schools		34
Number of lectures and demonstrations		254
Human nutrition, with demonstrations	152	
Home nursing	25	
Sewing	18	
Household management	14	
House furnishing	9	
Sanitation	18	
Reading in the home	5	
Music in the home	8	
Contests for children	5	
	254	

Number of persons receiving instruction:

Regular (five or ten lessons each)	989
Single admissions	367
Visitors	101
Public lectures	1,800

Canning clubs

Canning clubs were organized in Cortland County in order to test the value of such work for extension teaching in New York State. Each club was visited once in two weeks, and was instructed by means of demonstrations and explanations of canning processes.

Number of clubs	11
Total membership	181
Number of meetings held after June 24, 1914	51
Average attendance at meetings	10.9
Average number of persons in families represented	4.5
Number of visits in homes of members	29

Exhibits illustrating principles of canning fruits and vegetables were made at the Cortland County Fair (496 cans) and at the State Fair (100 cans).

RECOMMENDATIONS

It is recommended that the Department receive financial support which will enable it (1) to develop work already begun; (2) to add much-needed courses dealing with the problems of clothing; (3) to cooperate with the Department of Rural Education in adding courses in methods of teaching home economics; (4) to begin work in investigation in the laboratories and in the field; (5) to develop farm home extension work; (6) to complete the equipment of the building.

MARTHA VAN RENSSELAER,
FLORA ROSE,
Professors of Home Economics.

DEPARTMENT OF METEOROLOGY

TEACHING

The total number of students taking work in the Department during the year was 284, of whom 256 registered for the course given in the second term and 28 for the summer school. The course given in the second term is a three-hours lecture course open to all students. The course given in the summer school consisted of three lectures and one laboratory period each week.

WILFORD M. WILSON,
Professor of Meteorology.

FARM BUREAU OFFICE

Twenty-six counties out of a possible fifty-five in New York State now have farm bureaus. One county farm bureau is in its fourth year; two are in their third year; fifteen have been in operation between one and one and a half years; two for eight months; five for seven months; one for two months. Six or eight other counties are working on organization. The central office has received inquiries from twenty-three counties in the State regarding farm bureau work. Five sixths of the counties in the State have therefore shown interest in this movement. The following list shows the counties having bureaus, the date of organization, the manager, and the location of the headquarters office:

County	Date of organization	Manager	Headquarters
Allegany	July 1, 1913	F. C. Smith	Wellsville
Broome	March 1, 1911	E. R. Minns	Chamber of Commerce, Binghamton
Cattaraugus	June 10, 1913	H. K. Crofoot	Olean
Cayuga	April 1, 1914	J. R. Teall	Auburn
Chautauqua	January 15, 1913	H. B. Rogers	Chautauqua
Chemung	April 1, 1913	M. E. Chubbuck*	Chamber of Commerce, Elmira
Clinton	December 2, 1912	C. B. Tillson	Plattsburg
Cortland	February 24, 1913	E. H. Forristall	Cortland
Delaware	March 1, 1914	T. M. Avery	Walton
Dutchess	July 1, 1913	F. H. Lacy	Poughkeepsie
Erie	February 1, 1914	W. L. Markham	Chamber of Commerce, Buffalo
Franklin	April 1, 1913	O. F. Ross	Malone
Herkimer	December 2, 1912	†C. A. Taylor	Herkimer
Jefferson	April 16, 1912	F. E. Robertson	Watertown
Monroe	April 15, 1913	L. A. Toan	Chamber of Commerce, Rochester
Montgomery	March 9, 1914	A. S. Merchant	Canajoharie
Nassau	February 13, 1914	L. R. Simons	Mineola
Niagara	February 1, 1913	E. H. Anderson	Lockport
Oneida	November 1, 1912	G. W. Bush	Chamber of Commerce, Utica
Onondaga	May 1, 1913	S. A. Martin	112 Court House, Syracuse
Oswego	July 1, 1913	E. V. Underwood	Oswego
Otsego	February 1, 1914	F. S. Barlow	Cooperstown
St. Lawrence	February 15, 1913	C. S. Phelps	Canton
Tompkins	December 1, 1913	V. B. Blatchley	Ithaca
Ulster	March 3, 1914	W. H. Hook	County Building, Kingston
Wyoming	May 1, 1913	H. M. Bowen	Perry

* Appointment effective November 15, 1914.
† Appointment effective January 1, 1915.

ORGANIZATION

When the first farm bureaus were organized in this State, they were administered by a committee, formed as a rule on the initiative of a chamber of commerce. Examples of this method of organization are: Broome, Chemung, Jefferson, Oneida, and Cortland Counties. Later, in several counties farm improvement associations were formed in order to support

the work. During the past six months the effort to organize and develop farm bureau or farm improvement associations in counties having farm bureaus has been extended throughout the State, and these associations are now generally assuming the entire responsibility for the work of the bureau and of its manager. At the present time all but three counties have associations, and these will probably be changed in the near future.

Briefly, this general plan of organization is as follows: A number of citizens interested in the development of agriculture in the county come together on call of some leader, resolve themselves into a farm bureau or a farm improvement association, adopt a constitution and by-laws, and elect officers. An executive committee or board of directors of three to nine members (the usual number being seven) usually has power to administer all the policies and finances of the association, and to employ and fix the salary of a manager.

The second, and perhaps the most important, part of the plan is the appointment by the president, at the suggestion of the manager and with the approval of the executive committee, of what is known as an advisory council. This council is made up of persons representing each distinctive community in the county, and varies in number from fifteen to fifty. It meets quarterly to discuss with the executive committee the plans and policies of the association. The chief duties of the members of this council are, however, in their own localities, where they are the local leaders of the bureau work.

The idea behind this general plan is, first to develop local responsibility for the organization and administration of the affairs of the bureau, and then to encourage initiative on the part of each community in the county. The people of the county must first want the work done, and they must want it enough to organize and pay for it. Then they must plan and direct the work, and seek to have done what they think is most important. It is the old principle of self-help, in operation. A permanent force is established in the county, which insures the continuance of local effort if the cause is thought worth while, even after outside support is withdrawn.

FINANCES

The tables that follow show the receipts and expenses of the eighteen farm bureaus that were in operation in the State previous to March 1, 1914 (the latest date for which the figures are available), for the year ending on that date. They also show the financial resources of twenty-five farm bureaus that are now in operation, for the present calendar year.

Receipts.— It will be noted that there were two general sources of financial support of the bureaus, local support and that which comes from outside

agencies. It is worthy of comment, too, that practically the same amount of money was derived from each source.

The average receipts of the eighteen bureaus were about $3336. This is approximate, however, because several of the bureaus were not organized until the middle of the year.

Funds received from local sources		
Boards of supervisors	$14,733.33	
Subscriptions, including chambers of commerce*	10,678.28	
Memberships	1,583 00	
		$26,994 61
Funds received from agencies outside county		
United States Department of Agriculture	$11,720 00	
New York State Department of Agriculture	8,250 00	
Railroad companies†	4,287 64	
Chicago Crop Improvement Committee	6,020 00	
		30.277 64
Miscellaneous, including balances of previous year		2,780 59
Total of funds received from all sources		$60.052 84

*This amount includes the value of office supplies and stenographic help when furnished by chambers of commerce and not paid for in cash

† This does not include the value of passes granted by railroad companies to farm bureau managers in their respective counties The value of these passes is probably one hundred to three hundred dollars per year In addition, railroad companies have been liberal in granting passes to the men to attend agricultural meetings outside the county

Expenses.—The expenses of eighteen bureaus for a year amounted to $48,019.31, or approximately $2668 for each bureau. This does not include purchase of automobiles, which most of the bureaus used and which averaged about $530. It is hardly accurate to use these average figures, however, as not all the bureaus were in operation for a full year, nor did all of them possess automobiles even for part of the time; but they are the best figures available at the present time.

Salaries	$29,946.61
Traveling expenses	2,746.18
Office equipment and maintenance	947.94
Printing	978.11
Office rent*	3,246.00
Stenographic work	4,407.18
Automobile and livery	4,210.46
Miscellaneous	1,536.83

*This includes the estimated value of offices furnished by chambers of commerce, as well as office rent paid in cash In a few cases stenographic help is also furnished by chambers of commerce. The value of this is included under stenographic help

Resources.—The following statements give the estimated resources of twenty-five farm bureaus in the State for the calendar year 1914:

	Total		Average	
Local resources				
Boards of supervisors	$31,600 00		$1,264 00	
Subscriptions	9,107 00		364 28	
Memberships	3,314 00		132 56	
		$44,021.00		$1,760.84
Resources from outside county				
New York State	$15,000.00		$600 00	
United States Government	11,820.00		*472 80	
Railroad companies	5,870.00		234.80	
		32,690.00		1,307.80
Miscellaneous, including balances from 1913		7,866 56		314.66
Grand total		$84,577 56		$3,383.30

*Ten counties receive about $1200 each, the remainder receive $1 and the use of the government frank.

It will be noted that an increasing amount of the financial support of the bureaus is coming from local sources, $44,021 being provided locally as against $32,690 received from outside the county. The average resources are $3383.30 for each farm bureau during the present year. Funds from federal sources are likely to be increased during the current year. In fact, beginning August 1, four other counties have received $600 each from the Federal Government—Allegany, Cayuga, Oswego, and Wyoming Counties. This increases the total resources of twenty-five bureaus to nearly $87,000, or about $3500 each.

NATURE OF THE WORK

The kinds of work performed by the farm bureau managers and their associations are almost too numerous to mention. They may be classified, however, into five general groups:

1. Organization of the forces of a community
2. Leadership and initiative in rural affairs
3. Study of local economic conditions
4. The demonstration of better farm practices and management
5. Information and advice

1. *Organization.*—There are two distinct kinds of organization work performed by the farm bureau managers, one commercial and the other educational. An effort is being made to differentiate between these two. Commercial organizations are chiefly buying and selling associations. The farm bureau association itself is a good example of an unincorporated organization endeavoring to bring buyers and sellers of farm supplies and products together. Circular letter No. 17, and an article on *Why Pay One Dollar for Membership in a Farm Bureau Association*, will explain the nature of this work in more detail. These may be obtained by application to the College.

The organization work of the bureau managers is, however, chiefly along educational lines, although many of these may grow into commercial projects. The best examples of this work are probably the cow-testing association; the seed improvement association, especially for potatoes and corn; and breeders' clubs. The following list of projects under way in the different counties illustrates concretely this type of work. A project means that this line of work is being carried on in the county, and does not refer to the number of men doing this work. The accompanying table shows the total number of projects in all the counties:

Farmers' exchanges	4
Cow-testing associations	13
Farmers' clubs	1
Campaign for village improvement	1
Campaign for association membership	4

2. *Leadership and initiative.*—This kind of work may mean much or little, according to the vision of the manager. The opportunities for leadership in country life and for initiative in rousing the community to develop itself to its full economic and social possibilities are many. Probably the most conspicuous needs are for cooperation along economic and educational lines; for the improvement of markets, purchasing facilities, roads, and transportation service and rates; for increased efficiency of churches, schools, and public institutions; for the standardization of the croppage of the region, and especially with reference to state and national laws, as a means of securing a square deal for the community. Boys' and girls' club work also comes under this head—not so much the actual carrying on of the work, which should be done by school superintendents and teachers, but initiative and assistance in getting it under way. The exercise of these functions generally tends to arouse the individuals of a community to work together better. The following list of projects illustrates concretely the lines of work that are being followed in New York State:

Boys' and girls' club work	11
Canning clubs	2
Farm contests and improvements	2
Farm bureau picnics	4

3. *Economic studies.*—The most important work under this function is the farm survey, as it is now commonly known, both detailed and general. The detailed surveys are carried on (1) in order to find out the best local farm organizations and practices, (2) in order to study the farm management point of view, and (3) in order to apply findings to individual farms by the return of summarized records.

The introduction of cash accounts with enterprises, crops, and animals is another phase of this work, the object of which is to encourage a more scientific and accurate study of the farm business.

The following list of projects illustrates this field of work in New York State:

Farm surveys, under way and completed	7
Farm accounts, determining the cost of production	18
Rural credit	2

4. *Demonstrations.*—The demonstration of better farm practice in communities, with crops, animals, and soils, and the improvement of these, based both on science as represented by the College and Experiment Station and on the best practice of the community as learned by definite studies, is an important line of work and one that demands a large share of the attention of bureau managers. This work is shown by the following list of projects:

Lime tests	7
Growth of legumes	11
Improvement of dairy cattle	2
Orchard improvement	13
Spraying (potatoes and wild mustard)	10
Drainage	13
Pasture improvement	1
Seed selection	2

5. *Information and advice.*—From the point of view of the majority of farmers, this is the most important function of the farm bureau. Actually, it is doubtful whether this function is more than incidental. However, advice and information is sought about practically everything that human beings are capable of asking and answering. Certainly it is very necessary for the farm bureau manager to meet this demand of the community. Moreover, it serves to acquaint him with his people and with their con-

ditions and problems. In this respect it is of considerable value. Reliable information is needed in very many cases, but the managers are advised to use caution in giving advice. The following projects indicate the kinds of information and advice that are usually sought:

Fertilizer experiments and information	8
Variety tests of seed	6
The improvement of barns and other buildings	2
Extension schools, farmers' institutes, agricultural trains, and the like	7

SUPERVISION

Supervision of the farm bureaus in New York State is vested in a director and an assistant director, whose offices are located at the College of Agriculture at Ithaca. This office represents equally, and is jointly supported by, the United States Department of Agriculture, through the Office of Farmers' Cooperative Demonstrations; the State Department of Agriculture; and the State College of Agriculture. The director reports monthly to the officer in charge of the work in the United States Department of Agriculture, to the State Commissioner of Agriculture, and to the Director of the College. The following table illustrates the relationship of these institutions and the central office to the bureaus:

State Department of Agriculture	*State College and Experiment Station*	*United States Department of Agriculture*
Regulation	Information	Correlation
Organization	Instruction	Information
Finances	Extension	Finances

State Director's Office
Information
Organization
Administration
Cooperation
Stimulation

The 26 farm bureaus, and their managers, officers, and 800 committeemen

The function of the central office of the farm bureaus, which is located in the College of Agriculture, is first to assist in the organization of new bureaus in counties which are ready for them and where their organization is desired. In counties where bureaus are organized, the function of the central office is to administrate state and federal funds contributed to the local bureaus, and to inspect and keep in close touch with the work in the several counties, assisting in this work by advice and suggestion where necessary. The cen-

tral office also endeavors to correlate the work in the different counties and work out common policies that seem to be most advisable. The organization and methods of work in the different counties are being constantly studied, with the view to finding out the most successful and the least successful methods.

Professor L. S. Tenny, who was in charge of the work last year, resigned on January 1, 1914. Since then, the writer has filled his place. On December 1, 1913, H. E. Babcock was appointed Assistant State Director, giving part of his time to this work and part to the organization of a local farm bureau in Tompkins County.

The following list of activities of the central office for nine months indicates the nature of the work:

Total number of visits made to bureaus in the State	83
Total number of individual conferences held with the men aside from visits	112
Trips made to counties not having bureaus, in order to furnish information	11
Attendance at meetings at which the director spoke on farm bureau work	6,209
Total miles traveled by railroad by the director	17,300
Total miles traveled by automobile and by horse and buggy	1,310
Total number of days in office	114½
Total number of days in field	109
Total number of official letters written	2,289
Total number of circular letters sent out	26

TEACHING

During the second term of the college year 1913-1914, a special course was given in the Department of Rural Economy under the name of "Rural Organization." This course covered the relationship, history, organization, finances, functions, purposes, methods of work, and accomplishments of the farm bureaus in New York State, and was designed to familiarize students with the farm bureau movement. Sixteen students registered in the course, eleven of whom completed it.

PUBLICATIONS

The following publications have been prepared and issued during the year:

	Number of copies
Circular 1: Farm bureaus: what they are and how they are organized and financed in New York State. (Prepared by Professor Tenny, 1913)	5,000

		Number of copies
Circular 2:	Broome County: an account of its agriculture and of its farm bureau	6,000
Circular 3:	Dr. L. H. Bailey on the farm bureau movement	2,500
Circular 4:	Jefferson County: an account of its agriculture and of its farm bureau	6,000
Circular 93:	(State Department of Agriculture) The farm bureau movement in New York State	4,000

In addition to these circulars, a four-page mimeographed pamphlet, known as the Farm Bureau Monthly, has been issued since April, 1914. This is mailed to about 800 farm bureau officers and committeemen in the State, making 4800 pamphlets issued in six months.

RECOMMENDATIONS

Considering the fact that this Department has been organized for only about a year and a half, it is very well equipped except in the matter of office room. The only recommendation the writer has to make is that the space allotted to the Department be at least doubled. At present five persons are working in a room about 16 by 24 feet.

M. C. BURRITT,
Extension Professor, and Director of Farm Bureaus.

DEPARTMENT OF EXTENSION TEACHING

TEACHING

During the past year four courses were given in extension teaching. These courses aim to instill in the student an active interest in rural affairs by means of a study of rural conditions in general, and to teach the principles of organization and parliamentary practice. During the term each student was required to write four speeches and deliver them before the class. Parliamentary practice was given in connection with one course. Each student was given individual attention through a half-hour appointment each week. There was an increase in the number of students enrolled in the courses over the number of the previous year. The registration was as follows:

Course 1	115
Course 2	73
Course 3	24
Course 14	32
Total	244

Course 3 was given on request of a number of students who had taken courses 1 and 2 and who wished to take advanced work along the same lines. In this course a study was made of the organization of the extension work of this and other state agricultural colleges. Extension problems in general were studied, and each member of the class prepared and submitted a report on the application of extension teaching to some particular rural community in which he was interested.

The competition for the Eastman Stage aroused more interest than ever before. The winter-course stage and winter-course debates were also popular. The contestants in all these competitions were coached by members of the departmental staff.

EXTENSION

The extension activities arranged by the Department of Extension Teaching during the past year have followed mainly the lines of the preceding year. Those activities embodying continuous work, such as lecture courses, extension schools, and the like, were given special attention. There was an increased number of requests for individual lectures by members of the college staff before county and subordinate granges, fairs, agricultural and horticultural clubs, farmers' and teachers' institutes, dairymen's and poultrymen's associations, schools, churches, Christian associations, and farmers' picnics. These requests were filled whenever possible and when

the communities or associations served were willing to pay part of the traveling expenses.

Not all the requests for extension work came to the Department of Extension Teaching. Many activities were arranged directly by the departments concerned, and the reports for these should appear in their respective reports. As shown in the following list, 472 requests were filled through the Department of Extension Teaching. There was at these meetings an attendance of 48,420 persons.

A complete report of the Seventh Annual Farmers' Week is given. This report shows the increase in the attendance at this annual event, which is becoming one of the most important meetings in the State.

The report of the extension schools held during the past year shows a very large increase in this continuous line of work. In the preceding year 24 schools were held, while in the year just closed 61 schools were arranged.

Extension meetings by counties

County	Number of meetings	Attendance	Number of meetings with attendance not reported
Albany	4	940	3
Allegany	17	2,327	2
Broome	2	235	....
Cattaraugus	6	995	1
Cayuga	38	1,826	6
Chautauqua	15	979	4
Chemung	53	3,125	....
Chenango	4	450	....
Clinton	3	515	2
Columbia	5	384	2
Cortland	24	999	5
Delaware	6	801	1
Dutchess	5	371	5
Erie	15	1,535	3
Essex	4	425	1
Franklin	1	50	1
Fulton	2	47	....
Genesee	4	399	2
Greene	....	....	1
Hamilton	....	....	....
Herkimer	10	802	....
Jefferson	9	394	....
Kings	....	....	....
Lewis	8	548	....
Livingston	11	862	....
Madison	11	760	....
Monroe	10	2,146	5
Montgomery	....	....	2
Nassau	1	32	....

County	Number of meetings	Attendance	Number of meetings with attendance not reported
New York	3	1,915	....
Niagara	10	926	6
Oneida	20	1,819	4
Onondaga	18	1,648	5
Ontario	6	778	1
Orange	4	395	1
Orleans	4	355	1
Oswego	4	146	....
Otsego	5	803	2
Putnam	....	......	....
Queens	2	28	....
Rensselaer	3	168	....
Richmond	....	....	....
Rockland	....	...	.....
St. Lawrence	6	955	3
Saratoga	1	200	....
Schenectady	1	20	....
Schoharie	1	500	....
Schuyler	5	175	....
Seneca	8	455	.....
Steuben	14	921	......
Suffolk	1	18	....
Sullivan	11	690	4
Tioga	2	120	2
Tompkins	34	2,087	7
Ulster	5	317	1
Warren	2	240	1
Washington	2	175	1
Wayne	7	575	.....
Westchester	5	724	7
Wyoming	14	635	1
Yates	6	440	4
Total	472	40,175	97

Average attendance 85
Estimated total attendance for meetings, including those where attendance was not reported 48,420

Seventh Annual Farmers' Week

The Seventh Annual Farmers' Week was held February 9–14, 1914. The increase in attendance over former years shows a steady growth. The estimated probable attendance was 3500; the total registered attendance 2961. Deducting duplication, the total number of persons registered was 2551. Of these, eighty-six per cent were from New York State, representing fifty-eight counties. Persons were in attendance from nineteen States of the Union and three foreign countries.

The program this year was marked by a larger proportion of informal discussions, round-table talks, and laboratory exercises. A greater number of conventions and conferences held their meetings at the College during the week than formerly. Another feature was the introduction of several banquets of associations and entertainments arranged for the evenings. There were given during the week 305 lectures, 27 demonstrations, 32 round-table discussions, 33 laboratory exercises, 11 contests and competitions, and 7 banquets and entertainments. During the week 19 conventions and conferences held their meetings at the College. This organization work is yearly becoming more important.

Three speaking contests were held during the week, as shown below. The Fifth Annual Eastman Stage was held in Bailey Hall, which permitted of an attendance of nearly 2000 persons.

Eastman Stage
- B. W. Shaper, winner of first prize
- J. J. Swift, winner of second prize
- T. B. Charles
- R. F. Steve
- E. G. Perl
- D. S. Hatch

Winter-course Stage
- V. H. Roberts, General Agricultural Club, winner
- Miss Mary A. Wilson, Home Economics Club
- Miss W. Grace Osborne, Horticultural Club
- C. C. Calvert, Poultry Club

Morrison Debate (Winter course)
- Poultry Club, winner. Team,
  - C. C. Calvert
  - A. P. Leon
  - A. Horton

A summarized statement of the attendance and program of Farmers' Week follows:

Estimated attendance	3500
Total registered attendance	2961
Persons registered deducting duplication	2551
Number of counties in New York State represented	58
Proportion of attendance from New York State	86 per cent
Proportion of attendance from Tompkins County	20 per cent
States in the Union represented	19
Foreign countries represented	3

Day	Number of lectures	Number of demonstrations	Number of laboratory exercises	Number of round-table discussions	Number of contests and competitions	Number of entertainments and banquets
Monday.	32	2	3	2	1	0
Tuesday.	73	4	7	8	3	2
Wednesday. . . .	68	7	6	4	2	2
Thursday.	59	8	7	9	3	1
Friday	55	6	7	9	2	2
Saturday.	18	0	3	0	0	0
Total.	305	27	33	32	11	7

Number of cooperating lecturers from outside the College . . . 8[illegible]
Number of conventions and conferences 19

- Convention of the New York State Drainage Association
- Meeting of the Cornell Dairy Students' Association
- Meeting of the Home-makers' Conference
- New York State Country Church Conference
- Meeting of the Students' Association of the New York State College of Agriculture
- Meeting of the New York State Federation of Floral Clubs
- Meeting of the Rochester and Buffalo Florists' Clubs
- Meeting of the New York State Rural Engineering Society
- Meeting of the New York State Beekeepers' Association
- Meeting of the New York State Vegetable Growers' Association
- Conference of the Poultry Association and Clubs of New York State
- Home Garden Day — conference
- Rural School Education Conference (throughout the week)
- Fruit Growers' Conference
- Reunion of Winter-course Students
- Conference of Cornell Study Clubs
- Meeting of the Poultry Growers' Association of Ithaca
- Farm Boys' Conference
- Meeting of the Experimenters' League

The Department of Poultry Husbandry conducted three poultry shows:

- Blue Ribbon Poultry Show
- Egg Show

Number of exhibitions 14

Animal Husbandry
Dairy
Entomology
Farm Crops
Farm Management
Floriculture
Forestry
Home Economics
Plant Physiology
Potato Show
Poultry Husbandry
Rural Engineering
Rural School Education
Vegetable Gardening

Extension schools

During the winter, from December 1, 1913, to April 18, 1914, sixty-one extension schools were conducted. Of these, thirty were extension schools in agriculture and thirty-one in home economics. Thirty-one counties had one or more extension schools. The average attendance in the extension schools in agriculture was 40.43, and the average number of instructors was 3. In the schools in home economics, which were held usually in conjunction with the extension schools in agriculture, the average attendance was 31.93 and the average number of instructors was 2.

This year the number of instructors per school was reduced from an average of four to an average of three, and at the same time the tuition fee was reduced from $1.50 to $1. The smaller fee answered the same purpose as the larger one, that is, it served to eliminate the idle and curious, aroused local initiative, and covered about one half the traveling and incidental expenses.

A detailed report follows:

Town	County	Date	Registration		Total
			Agriculture	Home economics	
Ellington	Chautauqua	Dec. 1–6	24	16	40
Stamford	Delaware	Dec. 1–6	42	26	68
Lagrangeville	Dutchess	Dec. 8–13	40	24	64
Gouverneur	Saint Lawrence	Dec. 8–13	44	......	44
Horseheads	Chemung	Dec. 8–13	32	21	53
Dresserville	Cayuga	Dec. 15–20	41	......	41
Sherwood	Cayuga	Dec. 15–20	41	37	78
Hannibal	Oswego	Dec. 29–Jan. 2	32	16	48
Watkins	Schuyler	Dec. 29–Jan. 2	38	34	72
Johnstown	Fulton	Jan. 5–10	32	......	32
Greigsville	Livingston	Jan. 5–10	51	22	73
Arcade	Wyoming	Jan. 12–16	......	35	35
East Bloomfield	Ontario	Jan. 12–17	54	23	77

Town	County	Date	Registration		Total
			Agriculture	Home economics	
Warsaw	Wyoming	Jan. 12–17	38	....	38
Lowville	Lewis	Jan. 19–23	....	45	45
Mooer's Junction	Clinton	Jan. 19–24	40	28	68
Holley	Orleans	Jan. 19–24	47	....	47
Jacksonville	Tompkins	Jan. 19–24	40	....	40
Pike	Wyoming	Jan. 26–31	46	....	46
Ovid	Seneca	Jan. 26–31	37	44	81
Kinderhook	Columbia	Jan. 26–31	27	44	71
Burke	Franklin	Feb. 2–7	56	28	84
Lockport	Niagara	Feb. 2–7	78	36	114
Ithaca	Tompkins	Feb. 9–13	....	44	44
Union Springs	Cayuga	Feb. 16–21	21	17	38
Adams	Jefferson	Feb. 16–21	24	41	65
Meridian	Cayuga	Feb. 23–28	51	....	51
East Hampton	Suffolk	Feb. 23–28	59	....	59
Lake Placid	Essex	Feb. 23–27	....	26	26
Mount Vision	Otsego	Mar. 2–7	40	....	40
Almond	Allegany	Mar. 2–6	....	41	41
Liberty	Sullivan	Mar. 9–13	....	20	20
Dryden	Tompkins	Mar. 9–14	31	....	31
Monticello	Sullivan	Mar. 9–14	40	....	40
Worcester	Otsego	Mar. 16–20	....	26	26
Riverhead	Suffolk	Mar. 23–27	....	46	46
Brookhaven	Suffolk	Mar. 23–27	....	27	27
Hamburg	Erie	Mar. 23–28	57	....	57
Watertown	Jefferson	Mar. 30–Apr. 3	....	46	46
Hall	Ontario	Apr. 6–10	....	47	47
Ticonderoga*	Essex	Apr. 13–18	10	....	10
Elbridge	Onondaga	Apr. 20–24	....	37	37
Little Falls	Herkimer	Apr. 27–May 2	....	25	25
Manlius	Onondaga	May 4–9	....	25	25
Port Jervis	Orange	May 12–16	....	43	43

*Ticonderoga school adjourned at the middle of the week.

Total number of schools	61
Schools in agriculture	30
School in home economics	31
Counties in which schools were held	30
Total amount of time (weeks)	61
Total registration in schools in agriculture	1,213
Total registration in schools in home economics	990
Average registration in schools in agriculture	40.43
Average registration in schools in home economics	31.93
Total registration in extension schools 1913–1914	2,203

Fairs

During this last year, the College was called upon to send educational exhibits to thirty-seven town and county fairs in addition to the State Fair. This was an increase of nearly thirty per cent over the preceding year. At these fairs the representatives in charge of the exhibits gave in many instances special demonstrations and lectures. In each case the local fair

shared the transportation and traveling expenses with the College. At the State Fair eighteen departments of the College were represented by educational exhibits. The following table gives a summarized statement of these fairs. It was estimated that 390,000 persons were brought in touch with the College through these educational exhibits.

Number of fairs having college exhibits 38

Town	County	Date	Departments exhibiting
Perry	Wyoming	Aug. 11–13	Extension (general agriculture)
Fulton	Oswego	Aug. 11–14	Poultry Husbandry
Cortland	Cortland	Aug. 18–21	Entomology
Hornell	Steuben	Aug. 25–28	Poultry Husbandry
Watertown	Jefferson	Aug. 25–28	Plant Breeding
Moravia	Cayuga	Aug. 25–28	Extension (general agriculture)
New Hartford	Oneida	Aug. 26–28	Vegetable Gardening
Trumansburg	Tompkins	Aug. 25–28	Entomology
Trumansburg	Tompkins	Aug. 25–28	Entomology, Agricultural Chemistry
Avon	Genesee	Aug. 28–29	Dairy Industry
Lowville	Lewis	Aug. 25–28	Poultry Husbandry
Wellsville	Allegany	Sept. 1–4	Poultry Husbandry
Glen Spey	Sullivan	Sept. 2–4	Extension (general agriculture)
Greene	Chenango	Sept. 1–4	Dairy Industry
Rochester	Monroe	Sept. 7–19	Entomology
Poughkeepsie	Dutchess	Sept. 7–12	Animal Husbandry
Olean	Cattaraugus	Sept. 7–11	Poultry Husbandry
Plattsburg	Clinton	Sept. 7–11	Extension (general agriculture)
Dryden	Tompkins	Sept. 8–11	Farm Crops
Elmira	Chemung	Sept. 7–11	Dairy Industry
Hudson Falls	Washington	Sept. 8–11	Plant Pathology
Canandaigua	Ontario	Sept. 17–19	Pomology, Entomology
Penn Yan	Yates	Sept. 15–18	Plant Pathology
Cazenovia	Madison	Sept. 17	Dairy Industry
Ithaca	Tompkins	Sept. 15–18	Poultry Husbandry, Animal Husbandry
Malone	Franklin	Sept. 15–18	Farm Crops
Angelica	Allegany	Sept. 15–18	Poultry Husbandry
Batavia	Genesee	Sept. 16–19	Extension (general agriculture), Vegetable Gardening, Agricultural Chemistry
Cooperstown	Otsego	Sept. 22–24	Poultry Husbandry, Animal Husbandry, Vegetable Gardening, Agricultural Chemistry
Bath	Steuben	Sept. 22–25	Poultry Husbandry
Rome	Oneida	Sept. 21–24	Dairy Industry
Mineola	Nassau	Sept. 22–26	Entomology, Forestry
Hamburg	Erie	Sept. 22–25	Plant Pathology
Fonda	Montgomery	Sept. 29–Oct. 3	Plant Pathology, Extension (general agriculture)

Town	County	Date	Departments exhibiting
Hemlock	Livingston	Oct. 1–3	Soil Technology
Dundee	Yates	Sept. 29–Oct. 1	Entomology
Richfield Springs	Otsego	Sept. 28–30	Vegetable Gardening
Binghamton	Broome	Sept. 29–Oct. 3	Dairy Industry
Syracuse (New York State Fair)	Onondaga	Aug. 31–Sept. 5	Agricultural Chemistry, Pomology, Farm Management, Forestry, Extension Teaching, Plant Physiology, Home Economics, Floriculture, Soil Technology, Vegetable Gardening, Poultry Husbandry, Dairy Industry, Plant Breeding, Rural Engineering, Animal Husbandry, Farm Crops, Entomology, Plant Pathology

Farm trains

Six railroad traveling-schools were fitted out and run during the year ending September 30, 1914. Three of these were in cooperation with the New York Central and Hudson River Railroad, one was in cooperation with the Lehigh Valley Railroad, one with the New York, Ontario, and Western Railroad, and one with the Erie Railroad.

Summary

Summarizing the events described, arranged through the Department of Extension Teaching, the College has reached the following number of persons through such means as:

Individual extension lectures and lecture courses	48,420
Farmers' Week	3,500
Extension schools	2,203
Fairs	390,000
Railroad traveling-schools	20,083
	464,206

Report of traveling school in plant breeding

This train was run on the New York Central and Hudson River Railroad, October 27 to November 15, 1913. The representatives from the College were Professors Love and Myers, and Messrs. Livermore, Craig, Teeter, and Fisher.

Two coaches were used. One fourth of one coach was used for conferences and discussions, and the remainder of the space was used for the exhibit. The exhibit illustrated the results and methods of plant breeding at Cornell, particularly in regard to oats, barley, wheat, corn, timothy, and potatoes. Plants from the most striking types of timothy were displayed. Thirty-five or forty representative plants showing different types were shown. Bales of hay were shown to represent comparative yields of some of the better types of timothy grown, in comparison with that grown from commercial seed.

The exhibit covering cereal breeding included a display of typical heads and kernels from many different strains, together with comparative yields graphically represented by actual material in cases. Mounted specimens illustrated the Mendelian work with oats. Cases of material made up from the work of four years were used to illustrate the results of selecting corn for increased yield, maturity, and transmission of high-yielding qualities.

The potato exhibit illustrated the value of individual hill selection. This was represented by actual yields from breeding plats. The variation in yielding capacity of apparently equally good tubers was illustrated by samples taken from a field test. Comparative yields from base and apex were shown. The composition of a bushel of potatoes was graphically represented by actual constituents in jars. A few charts were displayed. Methods of investigative and extension work were illustrated by lantern slides. General views of the College and University were also shown by lantern slides and mounted photographs. The schedule was as follows:

Station	Date	Cars open	Attendance
Amsterdam	October 27	10 a. m. to 12 m	350
Fonda	October 27	2 p. m. to 6 p. m.	250
Palatine Bridge	October 27	7 p. m. to 9:30 p. m	300
Saint Johnsville	October 28	8:30 a. m. to 11:30 a. m.	200
Little Falls	October 28	1 p. m. to 3:30 p. m.	200
Herkimer	October 28	6 p. m. to 9:30 p. m	100
Oriskany	October 29	9 a. m. to 12 m	300
Richland	October 29	7 p. m. to 10 p. m.	50
Mexico	October 30	9 a. m. to 12 m.	40
Pulaski	October 30	7 p. m. to 10 p. m	75
Morse	October 31	9 a. m. to 12 m.	25
Pierrepont Manor	October 31	7 p. m. to 10 p. m	125
Adams	November 1	1 p. m. to 4 p. m	50
Watertown	November 1	7 p. m. to 10 p. m	100
Chaumont	November 3	8:30 a. m. to 12 m	150
Three Mile Bay	November 3	1:30 p. m. to 5 p. m	75
Cape Vincent	November 3	7 p. m. to 10 p. m	175
Great Bend	November 4	9 a. m. to 11 a. m	200
Carthage	November 4	1 p. m. to 4 p. m	125
Sacket Harbor	November 4	7 p. m. to 10 p. m	100
Evans Mills	November 5	10 a. m. to 12 m	150

Station	Date	Cars open	Attendance
Philadelphia	November 5	1:30 p. m. to 4:30 p. m.	50
La Fargeville	November 5	7 p. m. to 10 p. m.	300
Antwerp	November 6	10:30 a. m. to 12 m.	80
Gouverneur	November 6	2 p. m. to 5 p. m.	120
Canton	November 6	7 p. m. to 10 p. m.	500
Potsdam	November 7	10:30 a. m. to 12 m.	125
Norwood	November 7	1 p. m. to 3 p. m.	60
Massena	November 7	7 p. m. to 10 p. m.	75
Dekalb	November 8	11:30 a. m. to 2 p. m.	60
Heuvelton	November 8	2:45 p. m. to 4:15 p. m.	75
Ogdensburg	November 8	7 p. m. to 10 p. m.	25
Brierhill	November 10	8 a. m. to 10 a. m.	60
Hammond	November 10	1 p. m. to 4 p. m.	225
Redwood	November 10	7 p. m. to 10 p. m.	25
Sterlingville	November 11	9 a. m. to 12 m.	35
Lowville	November 11	7 p. m. to 10 p. m.	450
Lyons Falls	November 12	8 a. m. to 11 a. m.	75
Boonville	November 12	12:30 p. m. to 3:30 p. m.	100
Remsen	November 12	7 p. m. to 10 p. m.	150
Poland	November 13	9 a. m. to 12 m.	150
Newport	November 13	1:30 p. m. to 4:30 p. m.	300

The total attendance was 6180. The average attendance for the 42 towns was 147.

Report of traveling school in plant pathology and farm crops

This train was run over the main and northern divisions of the New York Central and Hudson River Railroad, July 20 to August 15, 1914. Representatives from the College were Professor M. F. Barrus and Messrs. J. H. Barron, R. J. Haskell, and W. M. Peacock. Representatives of the Agricultural Department of the New York Central Railroad also attended the train.

The train was arranged in the interests of potato growers of the State. One car was used. The exhibits displayed covered the following subjects: potato diseases, methods of preparing bordeaux mixture, methods of treating potato seed tubers with solutions of formaldehyde and corrosive sublimate, a cheap and convenient way of rigging a boom and pump for spraying potatoes. Results of experiments conducted at the College were shown to illustrate graphically the increased returns from individual hill selection and careful selection of seed.

Field meetings were held in the mornings and afternoons at various farms in the community surrounding each stop. In the evening farmers visited the car in order to view the exhibits and to hear lectures on subjects treated in the field meetings, such as potato diseases and their control, the culture and growth of potatoes, marketing, and the like.

Fifty-eight meetings were held and the total attendance was 2340. The average for each meeting was 40 persons. The schedule was as follows:

Potato demonstrations

July 20. Palmyra
Joseph Sawyer's farm — Forenoon 24
A. Vergow's farm — Afternoon 13
Evening 30

July 21. Clyde
H. S Fowler's farm — Forenoon 15
W. E. Meade's farm — Afternoon 3
Evening 20

July 22. Weedsport
C. H. Young's farm — Forenoon 30
A. H. Mappes' farm — Afternoon 36
Evening 40

July 23. Jordan (Rain all day)
Le Roy Monroe's farm — Forenoon 0
A. M. Nesbit's farm — Afternoon 5
Evening 10

July 24. Kirkville
Henry Goodell's farm — Afternoon 36
Evening 34

July 25. Oriskany
M. J. Fryer's farm — Forenoon 25
George J. Kline's farm — Afternoon 25
Evening 40

July 27. Boonville
Benjamin A. Capron's farm — Afternoon 30
Evening 20

July 28. Dickinson Center
Joseph Wood's farm — Forenoon 24
Walter Jesmur's farm — Afternoon 38
Evening 60

July 29. Owl's Head
Henry Childs' farm — Forenoon 35
Alva L. Hoose's farm — Afternoon 20
Evening 74

July 30. Malone
Leonard Frohock's farm — Forenoon 54
Earnest Gleason's farm — Afternoon 68
Evening 18

July 31. Constable
Fred A. Wright's farm — Forenoon 15
Theodore Fitch's farm — Afternoon 15

August 1. Halfway
Milo Clark's farm — Afternoon 18
Evening 20

August 3. Sennett
Arthur Huff's farm — Forenoon 60
Frank Riley's farm — Afternoon 82
Evening 40

August 4. Phelps
E. P. Hicks' farm — Afternoon 94
Evening 33

August 5. Clifton Springs
Edward Smith's farm — Afternoon 80
Evening 15

August 6. Holcomb
W. C. Buell's farm — Afternoon 125
Evening 45

August 7. Honeoye Falls
F. M. Plain's farm — Afternoon 70
Evening 5

August 8. Le Roy		
Eli Boldt's farm	Afternoon	80
	Evening	6
August 10. Akron		
H. G. Wilder's farm	Afternoon	37
	Evening	30
August 11. Lockport		
W. T. Hall's farm	Afternoon	80
	Evening	60
August 12. Middleport		
Paul Luckman & Sons' farm	Afternoon	50
	Evening	20
August 13. Spencerport		
Charles Zimmerman's farm	Forenoon	71
Barker Brothers farm	Afternoon	67
	Evening	45
August 14. Churchville		
Wm. Lehman's farm	Afternoon	47
	Evening	28
August 15. Pittsford		
Chauncey Smead's farm	Afternoon	115
	Evening	60

Report of traveling school in pomology

This train was run over the main lines of the New York Central and Hudson River Railroad, August 24 to 29 and September 7 to 12, 1914. Representatives from the College were Professor H. B. Knapp and Mr. F. E. Rogers. Representatives of the New York State Department of Agriculture, the Western New York Horticultural Society, and the New York State Fruit Growers' Association, also accompanied the train.

Two cars were used. One was equipped with apple packing and grading devices for demonstration purposes, the other for lectures and discussions. The purpose of the car was to present the provisions of the Wilson Apple-packing Law, which went into effect in this State on July 1, 1914, and to illustrate the packing and grading of apples as called for in this law.

The schedule of the train included stops and demonstrations at various places in the counties of Ulster, Greene, Albany, Rensselaer, Columbia, Dutchess, Monroe, Orleans, Niagara, Oswego, and Wayne. The total attendance was 4743. Twenty-nine stops were made, with an average attendance at each of 164 persons. The schedule was as follows:

Place	Date	Time	Attendance
Marlborough	August 24	9 a. m. to 12 m.	150
Ulster Park	August 24	2:15 p. m. to 4:30 p. m.	72
Saugerties	August 24	7 p. m. to 10 p. m.	14
Coxsackie	August 25	8:30 a. m. to 11:30 a. m.	105
Ravena	August 25	1 p. m. to 4 p. m.	54
Schodack Landing	August 26	8:30 a. m. to 11:30 a. m.	68
Stuyvesant	August 26	1 p. m. to 4 p. m.	125
Hudson	August 26	7 p. m. to 10 p. m.	115
Germantown	August 27	9 a. m. to 12 m.	200

Place	Date	Time	Attendance
Poughkeepsie	August 27	2 p. m. to 5 p. m.	160
Spencerport	August 28	9 a. m. to 12 m.	150
Brockport	August 28	1.30 p. m. to 4.30 p. m.	250
Albion	August 28	7 p. m. to 10 p. m.	400
Medina	August 29	10 a. m. to 1 p. m.	300
Lockport	August 29	2:45 p. m. to 5:45 p. m.	275
Fulton	September 7	1 p. m. to 4 p. m.	40
Oswego	September 7	7 p. m. to 10 p. m.	45
Hannibal	September 8	9 a. m. to 12 m	65
Red Creek	September 8	1:30 p. m. to 5:30 p. m.	200
Sodus	September 8	7 p. m. to 10 p. m.	300
Williamson	September 9	9 a. m. to 12 m	200
Webster	September 9	2:45 p. m. to 5:45 p. m.	180
Hilton	September 10	12:30 p. m. to 3:30 p. m.	225
Morton	September 10	7 p. m. to 10 p. m.	200
Lyndonville	September 11	1:30 p. m. to 4:30 p. m.	125
Barker	September 11	7 p. m. to 10 p. m.	300
Burt	September 12	8 a. m. to 11 a. m	150
Ransomville	September 12	1 p. m. to 4 p. m.	150
Wilson	September 13	8:30 p. m. to 10 p. m	125

Report of traveling school in farm crops, agricultural chemistry, and plant breeding

This train was run on the Elmira, Cortland, and Northern Division of the Lehigh Valley Railroad, March 2 to 13, 1914. Representatives from the College were Professors E. G. Montgomery, L. J. Cross, and C. H. Myers, and Messrs. F. E. Rice, W. M. Peacock, E. V. Hardenburg, W. T. Craig, J. R. Livermore and J. B. Reisner.

One coach was used. A member of each department was always present in order to answer questions and to explain the exhibits to visitors. No lectures were given on the car.

The farm crops exhibit consisted of six cases of grass, alfalfa, and clover plants, and several charts illustrating the following points: the distribution of the root systems of grass and clover, the characteristic root growth of alfalfa plants, and the importance of top-dressing timothy with fertilizer with the idea of permanence Charts, with statistics, were displayed in order to show the comparison of the yields of the principal crops of New York State with the yields in other leading States.

The Department of Agricultural Chemistry displayed different forms of lime and commercial fertilizers, and charts explaining home mixing, together with the ways of estimating the values of fertilizers on the market. Charts were also displayed showing the importance and value of the conservation of manures.

The exhibit of the Department of Plant Breeding bore out the importance of the selection of good seed in the production of large yields of timothy,

potatoes, and oats. Comparative yields from different seeds were represented, all being grown under the same conditions. Comparative yields of potatoes were shown which proved that seed selected from large hills gave greater yields than seed from small hills, other factors remaining the same.

The schedule for the school was as follows:

Place	Date	Time	Attendance
Cortland	March 2	11 a. m. to 8 p. m.	5
East Homer*	March 3	7 a. m. to 11 a. m.	......
Truxton*	March 3	11:40 a. m. to 8:10 p. m	.....
Sheds Corners*	March 4	8 a. m. to 11 a. m.	....
New Woodstock	March 4	1 p. m. to 4 p. m.	75
Groton	March 5	10 a. m. to 12 m.	15
Moravia	March 5	2 p. m. to 6 p. m.	50
Cato	March 6	12 m. to 4 p. m.	75
Aurora	March 6	6:48 p. m. to 10 p. m.	10
	March 7	8 a. m. to 12 m.	50
Lake Ridge	March 7	1 p. m. to 7 p. m.	75
Trumansburg	March 9	8 a. m. to 1 p. m.	25
Interlaken	March 9	3 p. m. to 9 p. m.	75
Hayt Corners	March 10	8 a. m. to 2 p. m.	40
MacDougall	March 10	3 p. m. to 6 p. m.	60
Honeoye Falls	March 11	8:30 a. m. to 10 a. m.	40
Lima	March 11	10:30 a. m. to 4 p. m	35
Mendon	March 12	8 a. m. to 12 m.	40
Oaks Corners	March 12	2 p. m. to 6 p. m.	20
Rushville	March 13	10:30 a. m. to 1:30 p. m	45
Total	......	......	735

*The train did not make these stops, as scheduled, because of a heavy snowfall and blizzard.

Report of traveling school in animal husbandry, poultry husbandry, and soil technology

This train was run on the New York, Ontario, and Western Railroad, March 16 to April 3, 1914. Representatives from the College were Professors E. O. Fippin and H. A. Hopper, and Messrs. C. C. Engle, W. W. Warsaw, R. S. Mosely, R. S. Banks, C. D. Smith, and J. H. Barron.

One coach was used. It was equipped for demonstration purposes. No lectures were held, but representatives from the College were present in order to explain the exhibits and to discuss questions brought up by visitors. Messrs. Rosenthal and Stone were with the car through Sullivan County and acted as interpreters for Jewish farmers.

The exhibit of the Department of Animal Husbandry illustrated the increased value of the offspring when pure-bred sires and pure-bred dams are used. Samples of all common foods used for feeding animals were shown, together with a tabulation of the food composition of each. Representative grain mixtures for various animals, and different kinds of roughage, were shown.

The exhibit of the Department of Poultry Husbandry contained models of poultry buildings illustrating recent improvements in poultry-house construction; labor-saving appliances, including feed hoppers, water fountains, and the like; a Cornell gasoline heater; and brief descriptive outlines of the important things to do in breeding poultry, feeding poultry, building poultry houses, hatching and rearing poultry, and the like.

The exhibit of the Department of Soil Technology covered the subjects of drainage, fertilizers, and lime. Various samples of tile were exhibited, showing different qualities, shapes, and junctions; and demonstration models and sets illustrated how a tile drain operates and the amount of water required to grow various crops, and, further, the amount of water retained in the root zone of various soils under different conditions. Tests in order to show the need of lime were made and explained, and it was shown how to slake lump lime on the farm. Various kinds of commercial fertilizer were shown, together with charts explaining the beneficial effects of drainage, lime, and fertilizers, and the various items of cost and limiting factors controlling their use.

Literature on all subjects covered by the exhibits was distributed. The schedule for the school was as follows:

Place	Date	Time	Attendance
Minetto	March 16	8:10 a. m. to 2:55 p. m	34
Pennellville	March 16	3:23 p. m. to 6:30 p. m	116
		Evening meeting	60
Caughdenoy	March 17	8:15 a. m. to 10:21 a. m	72
West Monroe	March 17	10:42 a. m. to 3:42 p. m	64
Constantia	March 17	3:50 p. m. to 6:30 p. m	51
State Bridge	March 18	11:14 a. m. to 3:30 p. m	44
Cleveland	March 18	4:05 p. m. to 6:30 p. m	100
Valley Mills	March 19	9:05 a. m. to 11:59 a. m	36
Sherburne Four Corners	March 19	1:26 p. m. to 4:45 p. m	58
Norwich	March 19	5:15 p. m. to 6:30 p. m	75
Randallsville	March 20	7:48 a. m. to 10:32 a. m	39
Bouckville	March 20	10:48 a. m. to 3:44 p. m	113
Clinton	March 20	4:25 p. m. to 6:30 p. m	62
		Evening meeting	100
Deansboro	March 21	8 a. m. to 11:10 a. m	134
Westmoreland	March 21	1 p. m. to 4:30 p. m	77
Oriskany Falls	March 23	8 a. m. to 11 a. m	193
Guilford	March 23	2:53 p. m. to 7:14 p. m	210
New Berlin	March 24	8 a. m. to 12 m	91
Edmeston	March 24	12:55 p. m. to 4 p. m	120
Mount Upton	March 25	8:25 a. m. to 12 m	141
Rockdale	March 25	12:58 p. m. to 6:35 p. m	100
Maywood	March 26	7:14 a. m. to 11:08 a. m	89
Franklin	March 26	11:16 a. m. to 8:17 p. m	52
Delhi	March 27	7:30 a. m. to 11 a. m	73
Hamden	March 27	11:30 a. m. to 1:54 p. m	69
Colchester	March 27	2:05 p. m. to 5:25 p. m	48

Place	Date	Time	Attendance
Walton....	March 28	8 a. m. to 12:15 p. m	116
Roscoe................	March 28	2:18 p. m. to 6 p. m..	136
Parksville...............	March 30	6:26 a. m. to 2:54 p. m	123
Luzon..................	March 30	3:30 p. m. to 6:30 p. m.......	314
Centerville.............	March 31	7:07 a. m. to 3:20 p. m	282
Kerhonkson............	April 1	7:30 a. m. to 8:37 a. m..	58
Accord....	April 1	8:45 a. m. to 12:15 p. m	32
Kyserike............ ..	April 1	12:24 p. m. to 5:05 p. m......	32
Ellenville..	April 2	8 a. m. to 10:30 a. m.........	205
Bloomingburg.	April 2	12:30 p. m. to 4 p. m	63
Little Britain.....	April 2	Evening meeting.	50
	April 3	7 a. m. to 8:42 a. m	24
Crystal Run...........	April 3	9:09 a. m. to 3:48 p. m.........	64

The total attendance was 3920. The average attendance for 41 meetings, including 3 evening meetings, was 96.

Report of traveling school in farm crops and dairy industry

This train was run over the lines of the Erie Railroad, with the New York State School of Agriculture, at Alfred University, cooperating, April 6 to 18, 1914. Representatives from the College were Professor C. D. Smith and Mr. J. H. Barron. Professor C. O. DuBois represented Alfred University.

One car was used. It contained exhibits demonstrating practical methods of farming. Especial emphasis was given to potato and milk production, to the construction of hotbeds, to plans for home gardens, and to the organization of potato clubs in the schools. Seventeen stops were made. The total attendance was 2165, the average attendance at each stop being 127. The schedule was as follows:

Place	Date	Time	Attendance
Canaseraga...............	April 6	8 a. m. to 10 a. m.............	221
Castile..................	April 6	12 m. to 5 p. m..............	95
Warsaw.....	April 6	Evening lectures.............	25
Warsaw.................	April 7	8 a. m. to 11 a. m...........	58
Attica..................	April 7	1 p. m. to 3 p. m...........	251
Avon..................	April 7	Evening lectures...	20
Avon..................	April 8	8 a. m. to 10 a. m.	54
Wayland....	April 8	12 m. to 7:30 p. m...........	315
Wayland................	April 8	Evening lectures.............	25
Cohocton...............	April 9	10 a. m. to 12 m............	204
Avoca.................	April 9	2 p. m. to 7:30 p. m..........	207
Avoca.................	April 9	Evening lectures.............	87
Bath..................	April 10	10 a. m. to 12 m............	65

Name	Date	Time	Attendance
Addison	April 10	2 p. m. to 9 p. m	144
Canisteo	April 10	Evening lectures	32
Canisteo	April 11	8 a. m. to 2 p. m	36
Hornell	April 11	3 p. m. to 5 p. m	34
Cuba	April 16	12 m. to 7.30 p m	34
Friendship	April 17	9 a. m. to 2 p. m	70
Belmont	April 17	3 p. m. to 6 p. m	70
Wellsville	April 18	8 a. m. to 9 a. m	50
Andover	April 18	10 a. m. to 2 p. m	68

Experimenters' League

At the annual meeting of the Experimenters' League, held in February, it was voted to continue the work of the organization. A few new names have been added to the membership list during the past year. Correspondence was carried on with each member, and forty-two experiments were arranged for and carried out. The reports on these experiments will be presented at the next annual meeting. The following table shows the distribution of the membership and the experiments:

Total membership enrolled.............................. 999

Membership by counties:

Albany	12	Niagara	18
Allegany	10	Oneida	35
Broome	17	Onondaga	34
Cattaraugus	10	Ontario	36
Cayuga	29	Orange	15
Chautauqua	32	Orleans	17
Chemung	8	Oswego	26
Chenango	20	Otsego	17
Clinton	4	Queens	4
Columbia	11	Rensselaer	12
Cortland	19	Rockland	4
Delaware	13	Richmond	5
Dutchess	16	Saint Lawrence	31
Erie	25	Saratoga	13
Essex	12	Schenectady	10
Franklin	11	Schoharie	9
Fulton	4	Schuyler	10
Geneseo	36	Seneca	22
Greene	6	Steuben	22
Herkimer	9	Suffolk	14
Jefferson	21	Sullivan	1
Kings	11	Tioga	11
Lewis	7	Tompkins	144
Livingston	10	Ulster	15
Madison	17	Washington	5
Monroe	29	Wayne	15
Montgomery	7	Westchester	10
Nassau	1	Wyoming	13
New York	16	Yates	8

Experiments carried on by members of the league:

Alfalfa	7	Lime	2	Tomatoes	1
Crops	1	Melons	1	Soy beans	1
Beans	1	Meadow	1	Rye	1
Clover	3	Potatoes	5	Vetch	2
Corn	3	Poultry	5	Fruit	1
Ginseng	1	Soils	1	Preserving eggs	1
Fertilizers	3	Sweet peas	1		
Gardening	2	Timothy	3		

Correspondence

The correspondence of the Department has increased nearly one third during the past year. The following is a report of the letters received and sent out:

Letters received	39,715
Letters sent out	36,244

Extension work by counties

In the following table is given an itemized report of the extension activities arranged by the Department of Extension Teaching, showing the distribution by counties. In addition to this report there follows a report showing the distribution of these activities by town, the date, and the representative of the College attending.

Albany	
Lectures and exhibits	10
Reading-course clubs	1
Farm visits	1
Farm train demonstrations	2
Total extension activities	14
Allegany	
Lectures	16
Extension schools in home economics	1
County fair exhibits	2
Total extension activities	19
Broome	
Lectures and exhibits	6
Conferences	1
County fair exhibits	1
Total extension activities	8
Cattaraugus	
Lectures and exhibits	10
Farm visits and inspection trips	1
County fair exhibits	1
Total extension activities	12

Cayuga	
Lectures and exhibits	48
Extension schools in agriculture	4
Conferences	2
Extension schools in home economics	2
Contests	1
Farm visits and inspection trips	10
Farm train demonstrations	5
Total extension activities	72
Chautauqua	
Lectures and exhibits	20
Reading-course clubs	2
Extension schools in agriculture	1
Extension schools in home economics	1
Farm visits and inspection trips	2
Total extension activities	26
Chemung	
Lectures and exhibits	5
Extension schools in agriculture	1
Extension schools in home economics	1
Farm visits and inspection trips	2
Cooperative experiments	1
Conferences	1
County fair exhibits	2
Total extension activities	13
Chenango	
Lectures and exhibits	5
Farm visits and inspection trips	2
Contests	1
Farm train demonstrations	7
County fair exhibits	1
Total extension activities	16
Clinton	
Lectures and exhibits	2
Extension schools in agriculture	1
Extension schools in home economics	1
County fair exhibits	1
Total extension activities	5
Columbia	
Lectures	2
Extension schools in agriculture	1
Extension schools in home economics	1
Farm train demonstrations	3
Total extension activities	7
Cortland	
Lectures and exhibits	29
Cooperative experiments	2
Conferences	1
Farm visits and inspection trips	3
Farm train demonstrations	4
County fair exhibits	1
Total extension activities	40

Delaware	
Lectures and exhibits	2
Extension schools in agriculture	1
Extension schools in home economics	1
Farm train demonstrations	6
Conferences	1
Total extension activities	11
Dutchess	
Lectures and exhibits	4
Conferences	2
Extension schools in agriculture	1
Extension schools in home economics	1
Farm visits and inspection trips	3
Cooperative experiments	1
County fair exhibits	1
Farm train demonstrations	1
Total extension activities	14
Erie	
Lectures and exhibits	20
Farm visits and inspection trips	6
Extension schools in agriculture	1
County fair exhibits	1
Farm train demonstrations	1
Total extension activities	29
Essex	
Extension schools in agriculture	1
Extension schools in home economics	1
Conferences	2
Lectures	4
Total extension activities	8
Franklin	
Lectures	1
Extension schools in agriculture	1
Extension schools in home economics	1
Conferences	2
County fair exhibits	1
Farm visits	6
Farm train demonstrations	3
Total extension activities	15
Fulton	
Extension schools in agriculture	1
Total extension activities	1
Genesee	
Lectures	5
Farm visits	3
Reading-course clubs	1
County fair exhibits	4
Farm train demonstrations	1
Total extension activities	14

Greene	
Lectures	1
Farm train demonstrations	1
Total extension activities	2
Herkimer	
Lectures and exhibits	5
Farm visits and inspection trips	1
Extension schools in home economics	1
Conferences	1
Reading-course clubs	1
Farm train demonstrations	4
Total extension activities	13
Jefferson	
Lectures and exhibits	3
Extension schools in agriculture	1
Extension schools in home economics	2
Farm train demonstrations	15
County fair exhibits	1
Total extension activities	22
Lewis	
Lectures and exhibits	3
Contests	2
Extension schools in home economics	1
Reading-course clubs	1
Farm train demonstrations	2
County fair exhibits	1
Farm visits	2
Total extension activities	12
Livingston	
Lectures and exhibits	9
Farm visits and inspection trips	2
Extension schools in agriculture	1
Conferences	1
Extension schools in home economics	1
Cooperative experiments	1
Farm train demonstrations	1
County fair exhibits	1
Total extension activities	17
Madison	
Lectures and exhibits	16
Conferences	1
Reading-course clubs	1
Farm visits and inspection trips	2
Cooperative experiments	1
Farm train demonstrations	7
County fair exhibits	1
Total extension activities	29

Monroe	
Lectures and exhibits	30
Farm visits and inspection trips	6
Cooperative experiments	4
Conferences	3
Farm train demonstrations	10
County fair exhibits	1
Total extension activities	54
Montgomery	
Lectures and exhibits	1
Farm train demonstrations	4
Conferences	2
County fair exhibits	2
Farm visits and inspection trips	5
Total extension activities	14
Nassau	
Cooperative experiments	1
Reading-course clubs	1
County fair exhibits	2
Total extension activities	4
New York	
Lectures	4
Farm visits and inspection trips	1
Total extension activities	5
Niagara	
Lectures and exhibits	11
Extension schools in agriculture	1
Extension schools in home economics	1
Farm visits and inspection trips	4
Cooperative experiments	1
Farm train demonstrations	6
Total extension activities	24
Oneida	
Lectures and exhibits	9
Reading-course clubs	1
Farm visits and inspection trips	7
Farm train demonstrations	11
County fair exhibits	2
Total extension activities	30
Onondaga	
Lectures and exhibits	12
Cooperative experiments	1
Farm visits and inspection trips	6
Farm train demonstrations	3
Extension schools in home economics	2
Total extension activities	24

Ontario	
Lectures and exhibits	10
Farm visits and inspection trips	8
Extension schools in agriculture	1
Extension schools in home economics	2
Farm train demonstrations	4
County fair exhibits	2
Conferences	1
Total extension activities	28
Orange	
Lectures and exhibits	5
Extension schools in home economics	1
Farm visits and inspection trips	5
Farm train demonstrations	3
Total extension activities	14
Orleans	
Lectures and exhibits	6
Extension schools in agriculture	1
Farm train demonstrations	3
Total extension activities	10
Oswego	
Lectures and exhibits	5
Farm visits and inspection trips	1
Contests	1
Extension schools in agriculture	1
Extension schools in home economics	1
Cooperative experiments	1
Farm train demonstrations	14
County fair exhibits	1
Total extension activities	25
Otsego	
Lectures and exhibits	5
Contests	2
Extension schools in agriculture	1
Reading-course clubs	1
Farm visits and inspection trips	1
Conferences	2
Extension schools in home economics	1
Farm train demonstrations	2
County fair exhibits	5
Total extension activities	20
Putnam	
Farm visits and inspection trips	1
Total extension activities	1
Queens	
Lectures and exhibits	4
Farm visits and inspection trips	1
Total extension activities	5

Rensselaer	
Lectures and exhibits	2
Farm train demonstrations	1
Total extension activities	3
Rockland	
Farm visits and inspection trips	1
Total extension activities	1
Saint Lawrence	
Lectures and exhibits	9
Extension schools in agriculture	1
Farm train demonstrations	10
Conferences	3
Total extension activities	23
Saratoga	
Lectures and exhibits	2
Farm visits and inspection trips	1
Total extension activities	3
Schenectady	
Lectures and exhibits	2
Reading-course clubs	1
Total extension activities	3
Schoharie	
Lectures and exhibits	1
Reading-course clubs	1
Farm visits and inspection trips	2
Total extension activities	4
Schuyler	
Lectures and exhibits	4
Extension schools in agriculture	1
Conferences	2
Farm visits and inspection trips	1
Extension schools in home economics	1
Total extension activities	9
Seneca	
Lectures and exhibits	13
Contests	1
Conferences	2
Extension schools in home economics	1
Extension schools in agriculture	1
Farm train demonstrations	8
Total extension activities	26
Steuben	
Lectures and exhibits	11
Reading-course clubs	1
Farm visits and inspection trips	2
Cooperative experiments	1
County fair exhibits	2
Total extension activities	17

Suffolk	
Lectures and exhibits	1
Farm visits and inspection trips	1
Cooperative experiments	2
Extension schools in agriculture	1
Extension schools in home economics	2
Total extension activities	7
Sullivan	
Lectures and exhibits	6
Extension schools in agriculture	1
Conferences	3
County fair exhibits	1
Extension schools in home economics	1
Farm train demonstrations	7
Total extension activities	19
Tioga	
Lectures and exhibits	8
Farm train demonstrations	1
Total extension activities	9
Tompkins	
Lectures and exhibits	35
Extension schools in agriculture	2
Conferences	1
Extension schools in home economics	1
Farm visits and inspection trips	6
Farm train demonstrations	5
County fair exhibits	4
Total extension activities	54
Ulster	
Lectures and exhibits	3
Farm train demonstrations	7
Reading-course clubs	1
Total extension activities	11
Warren	
Farm visits and inspection trips	1
Cooperative experiments	1
Total extension activities	2
Washington	
Lectures and exhibits	1
Reading-course clubs	1
Total extension activities	2
Wayne	
Lectures and exhibits	11
Farm visits and inspection trips	5
Farm train demonstrations	5
Total extension activities	21

Westchester	
Lectures and exhibits	1
Reading-course clubs	1
Farm visits and inspection trips	7
Total extension activities	9
Wyoming	
Lectures and exhibits	7
Extension schools in agriculture	2
Extension schools in home economics	1
Conferences	1
County fair exhibits	2
Total extension activities	13
Yates	
Lectures and exhibits	12
Farm visits and inspection trips	2
Contests	1
Farm train demonstrations	1
Total extension activities	16

Summary of extension work, October 1, 1913, to September 30, 1914

Lectures and exhibits	452
Farm train demonstrations	168
Farm visits and inspection trips	120
Reading-course clubs	16
Extension schools in agriculture	30
Extension schools in home economics	31
Cooperative experiments	17
Conferences	36
Contests	9
County fair exhibits	45

Meetings arranged by Department of Extension Teaching

Place	Time	Kind of meeting	Speaker
Merrifield	October 2	Lecture	John Bentley, jr.
Searsburg	October 2	Lecture	J. L. Stone
Auburn	October 6	Lecture	E. W. Benjamin
Aurelius	October 10	Lecture	H. A. Hopper
New Woodstock	October 11	Lecture	Miss Knowlton H. A. Hopper
Rochester	October 13	Lecture	C. H. Tuck
Venice Center	October 14	Lecture	Miss Fish
Greigsville	October 14	Conference	C. H. Tuck
Lenton Center	October 16	Lecture	H. B. Knapp
Dutchess County	October 17	Conference	C. H. Tuck
Springport	October 20	Lecture	Miss Nye
Tulsa, Oklahoma	Oct. 22–Nov. 1	Conferences	
Hubbardsville	October 22	Lecture	R. H. Wheeler
Five Corners	October 22	Lecture	H. B. Knapp
Ithaca	October 24–25	District School Superintendents' Meeting (College)	C. H. Tuck
Springport	October 24	Lecture	Miss Nye
Fairhaven	October 25	Lecture	H. B. Knapp
Hancock	October 25	Lecture	H. A. Hopper
Dresserville	October 27	Lecture	R. H. Wheeler
Binghamton	October 27	Lecture	C. H. Tuck
Oneonta	October 27	Lecture	C. H. Tuck
Little Falls	October 28	Lecture	C. H. Tuck
Johnstown	October 29	Conference	C. H. Tuck

Meetings arranged by Department of Extension Teaching continued

Place	Time	Kind of meeting	Speaker
Watkins	October 29	Conference	C. H. Tuck
Ticonderoga	October 30	Conference	C. H. Tuck
Malone	October 31	Lecture	C. H. Tuck
Gouverneur	November 3.	Conference	C. H. Tuck
Merrifield	November 6	Lecture	R. H. Wheeler
Horseheads	November 6	Conference	C. H. Tuck
Gloversville	November 10	Lecture	Members of Department of Poultry Husbandry
Washington, D. C.	Nov. 10–11	Association Farmers' Institute Workers	
East Venice.	November 11.	Lecture	Miss Moses
Washington, D. C.	November 11	American Association for the Advancement of Agricultural Teaching	
Washington, D. C.	Nov. 12–14	American Association of Agricultural Colleges and Experiment Stations.	
Yonkers	Nov. 12–15	Lectures	L. M. Hurd
Springport	November 12	Lecture	Royal Gilkey
Elmira	Nov. 13–15.	Lectures	W. G. Krum
Binghamton	Nov. 14–24	Lectures	L. M. Hurd
West Bloomfield	November 15	Lecture	A. E. Wilkinson
Binghamton	Nov. 17–24	Lectures.	W. G. Krum
Ellington	November 18	Conference	A. C. King
Stamford	November 19	Conference	C. H. Tuck
Little Falls.	November 20	Lecture	C. H. Tuck
Whitestown.	November 21	Lecture	C. H. Tuck
Oswego	November 22	Conference	R. H. Wheeler
Kenwood	November 22	Conference	R. H. Wheeler
Ithaca.	Nov. 24–25	Normal Institute (College)	
Buffalo	Nov. 25–29	Lectures	W. G. Krum
Albany	November 25	Lecture	J. E. Rice
Buffalo	November 26	Lecture	J. E. Rice
Saint Louis, Missouri	Nov. 27–28	Lectures	J. E. Rice
Ovid	November 29	Conference	A. C. King
Gilboa	December 1.	Lecture	L. M. Hurd
Ellington	December 1–6	Extension school	A. C. King C. D. Smith M. F. Barrus
Stamford	December 1–6	Extension school	H. A. Hopper L. M. Hurd J. L. Stone
New York	December 2–6	Crystal Palace Show	W. G. Krum
Frewsburg	December 2.	Lecture	E. O. Fippin
Mooers	December 3.	Lecture	C. H. Tuck
Saratoga Springs	December 3–6.	Lectures	R. S. Moseley
Sinclairville	December 3.	Lecture	E. O. Fippin
Watertown	December 4.	Conference	C. H. Tuck
West Niles	December 4.	Lecture	C. C. Engle
Perry	December 4.	Lecture	E. O. Fippin
Syracuse	Dec. 8–13	Lectures	W. G. Krum
Jamestown	Dec. 8–13	Lectures	R. S. Moseley
Lagrangeville	Dec. 8–13	Extension school	C. D. Smith E. O. Fippin H. B. Knapp
Gouverneur	Dec. 8–13.	Extension school	H. A. Hopper L. M. Hurd C. S. Phelps
Horseheads.	Dec. 8–13	Extension school	A. C. King M. F. Barrus G. P. Scoville F. A. Salisbury
Corning.	Dec. 9–12	Lectures	L. M. Hurd
Syracuse.	Dec. 9–12	State Dairymens' Association	C. H. Tuck
Edmeston	December 9.	Lecture	H. H. Wing
Hubbardsville	December 10.	Lecture	J. L. Stone
Berkshire	December 12.	Lecture	A. W. Gilbert
Unadilla	December 12.	Lecture	A. E. Wilkinson
Monticello.	December 12.	Lecture	R. H. Wheeler
Rochester	December 13.	Lecture.	E. O. Fippin C. H. Myers
Rochester	Dec. 15–20	Lectures	R. S. Moseley
South Wales	Dec. 15–20	Conferences	A. E. Wilkinson

Meetings arranged by Department of Extension Teaching (continued)

Place	Time	Kind of meeting	Speaker
Washingtonville	December 15	Lecture	E. S. Savage
Dresserville	Dec. 15–20	Extension school	H. A Hopper
			F. A. Salisbury
			E. O. Fippin
			E. V. Underwood
Sherwood	Dec. 15–20	Extension school	A. C. King
			M. F. Barrus
			L. M. Hurd
			K. C. Livermore
Fulton	Dec. 16–18	Lectures	W. G. Krum
Dryden	December 16.	Conference	C. H. Tuck
Union Springs	December 17.	Lecture	Miss Van Rensselaer
Sherwood	December 17.	Conference	K. C. Livermore
Fulton	December 18.	Lecture	W. G. Krum
Yonkers	Dec. 19–23	Lectures	L. M Hurd
Phelps	December 19	Lecture	E. S. Guthrie
Sherwood	December 19.	Conference	Members of Department of Home Economics
Warsaw	December 20.	Conference	C. H. Tuck
New York City	Dec. 26–31	Lectures	W. G. Krum
South Wales	December 27.	Lecture	A. E. Wilkinson
			Miss Van Rensselaer
Rochester	Dec. 29–Jan. 4	Lectures	R. S Moseley
Hannibal	Dec 29–Jan. 2	Extension school	A. C. King
			M. F. Barrus
			L. J. Cross
Watkins	Dec. 29–Jan. 2	Extension school	H. B. Knapp
			H. A. Hopper
			E. O. Fippin
Syracuse	December 30.	Teachers of agriculture	C. H. Tuck
Gouverneur	December 30.	Lecture	J. E. Rice
New York	December 31.	Lecture	W. G. Krum
Pittsford	January 3	Lecture	W. G. Krum
Waterburg	January 3	Lecture	C. H. Tuck
Johnstown	January 5–10.	Extension school	E. O. Fippin
			F. A. Salisbury
			W. G. Krum
			Edward Van Alstyne
			L. J. Cross
Greigsville	Jan. 5–10	Extension school	L. M. Hurd
			D. J. Crosby
			H. A. Hopper
			A. C. King
			M. F. Barrus
Frewsburg	January 6	Lecture	H. A. Hopper
Bergen	January 6	Lecture	Royal Gilkey
Jefferson	January 8.	Lecture	R. S. Moseley
Perry	January 8	Lecture	H. A. Hopper
Hoosick Falls	January 9	Lecture	R. S. Moseley
Utica	Jan. 12–17	Lectures	Members of Department of Poultry Husbandry
Utica	Jan. 12–17	Breeders' Association	C. H Tuck
Derby	January 12	Lecture	E. S. Savage
East Bloomfield	Jan. 12–17	Extension school	A. C King
			L M. Hurd
			H. A. Hopper
			D. J. Crosby
			Mrs. Morgan
			A. R. Mann
Warsaw	Jan. 12–17	Extension school	F. A. Salisbury
			H. B. Knapp
			M. F. Barrus
			H. A. Hopper
			W. L. Markham
Buffalo	January 13	Lecture	J. E. Rice
North Collins	January 13	Lecture	E. O. Fippin
Sherburne	January 13	Lecture	H. H. Wing
Utica	January 14	Lecture	J. E. Rice
Hubbardsville	January 14	Lecture	H. H. Wing
Albany	January 16	Young Men's Christian Association	C. S. Wilson
Waverly	Jan. 19–24	Lectures	L. M. Hurd

Meetings arranged by Department of Extension Teaching (continued)

Place	Time	Kind of meeting	Speaker
Mooers	Jan. 19–24	Extension school	E. O. Fippin
			J. Van Wagenen
			O. F. Ross
			C. B. Tillotson
			C. J. Mulvey
Holley	Jan. 19–24	Extension school	C. D. Smith
			M. F. Barrus
			D. J. Crosby
Jacksonville	Jan. 19–24	Extension school	A. C. King
			H. A. Hopper
			L. M. Hurd
			R. I. Davidson
Albany	January 20	Lecture	C. H. Tuck
Lincoln	January 22	Agricultural school	G. W. Cavanaugh
Palmyra	January 24	Lecture	R. S. Moseley
Pike	Jan. 26–31	Extension school	H. A. Hopper
			W. G. Krum
			W. L. Markham
			F. A. Salisbury
			C. O. DuBois
Ovid	Jan. 26–31	Extension school	M. F. Barrus
			C. D. Smith
			R. S. Moseley
			E. G. Montgomery
			R. I. Davidson
			L. M. Hurd
Kinderhook	Jan. 26–31	Extension school	A. C. King
			J. Van Wagenen
			A. E. Wilkinson
Rochester	Jan. 28–30	Western New York Fruit Growers' Association	C. H. Tuck
Canton	January 29	Lecture	C. H. Tuck
Bellona	January 29	Lecture	L. M. Hurd
Martville	January 29	Lecture	H. H. Wing
De Ruyter	January 30	Lecture	J. E. Rice
Kenwood	January 30	Lecture	H. H. Wing
Berkshire	January 30	Lecture	R. S. Moseley
West Winfield	January 31	Lecture	H. H. Wing
Utica	January 31	Lecture	A. W. Gilbert
Boonville	February 2	Lecture	Miss Titsworth
Burke	Feb. 2–7	Extension school	H. A. Hopper
			O. F. Ross
			L. J. Cross
			C. B. Tillotson
Lockport	Feb. 2–7	Extension school	A. C. King
			C. D. Smith
			C. R. Crosby
			D. J. Crosby
Poughkeepsie	Feb. 3–6	State Grange meeting	C. H. Tuck
Ithaca	February 3	Winter course	C. H. Tuck
Frewsburg	February 3	Lecture	E. S. Savage
Sinclairville	February 4	Lecture	H. B. Knapp
Rochester	Feb. 4–5	State Breeders' Association	D. F. Howe
Perry	February 5	Lecture	H. B. Knapp
North Collins	February 6	Lecture	A. L. Thompson
Ithaca	February 10	Association for the Promotion of Agricultural Education	T. B. Wilson
Meridian	February 16	Lecture	E. S. Guthrie
Genoa	February 16	Lecture	W. G. Krum
Wayland	February 16	Lecture	L. M. Hurd
Union Springs	Feb. 16–21	Extension school	M. F. Barrus
			H. A. Hopper
			L. M. Hurd
			J. L. Stone
Adams	Feb. 16–21	Extension school	Miss Birdseye
			Miss Knowlton
Cortland	February 17	Lecture	E. S. Savage
Akron	February 17	Lecture	W. G. Krum
Rochester	February 17	Lecture	L. M. Hurd
Rochester	February 18	Lecture	W. G. Krum
Henrietta	February 18	Lecture	L. M. Hurd
Berkshire	February 18	Lecture	R. S. Moseley
Hinsdale	February 19	Lecture	W. G. Krum
Union Springs	February 19	Lecture	L. M. Hurd

Meetings arranged by Department of Extension Teaching (continued)

Place	Time	Kind of meeting	Speaker
Bouckville	February 19	Lecture	R. S. Moseley
Poolville	February 19	Lecture	R. S. Moseley
East Otto	February 20	Lecture	W. G. Krum
Union Springs	February 20	Lecture	L. M. Hurd
Cayuga	February 20	Lecture	R. S. Moseley
Trumansburg	February 21	Lecture	G. C. Supplee
East Otto	February 21	Lecture	J. E. Rice W. G. Krum
Pawling	February 21	Lecture	L. M. Hurd
Oxford	February 21	Lecture	R. S. Moseley
Alfred	Feb. 23–26	Farmers' Week	C. H. Tuck W. G. Krum J. L. Stone E. G. Montgomery A. E. Wilkinson
Meridian	Feb. 23–28	Extension school	M. F. Barrus J. B. Bain D. J. Crosby R. S. Moseley F. A. Salisbury
East Hampton	Feb. 23–28	Extension school	A. C. King A. E. Wilkinson L. M. Hurd H. A. Hopper
Red Creek	February 24	Lecture	E. O. Fippin
Sherburne	February 24	Lecture	H. W. Riley
Hubbardsville	February 25	Lecture	H. W. Riley
Holley	February 25	Lecture	E. O. Fippin
Canandaigua	February 25	Lecture	I. R. Davidson
Albion	February 25	Lecture	J. E. Rice T. E. Schreiner
Binghamton	February 26	Lecture	G. P. Scoville Miss Moses
Newark	February 26	Lecture	T. E. Schreiner
Albany	February 27	Lecture	J. E. Rice
Sinclairville	February 27	Lecture	A. L. Thompson
Lincolndale	February 27	Lecture	H. W. Riley
Huntington	February 27	Lecture	L. M. Hurd
Dansville	February 27	Lecture	H. B. Knapp
Kenwood	February 27	Lecture	E. O. Fippin
Perry	February 28	Lecture	A. L. Thompson
Castile	February 28	Lecture	W. G. Krum
Saratoga	February 28	Lecture	J. E. Rice
Mount Vision	Feb. 2–7	Extension school	A. C. King C. C. Engle W. G. Krum H. A. Hopper M. Fairchild
La Salle	February 2	Lecture	R. S. Moseley
Frewsburg	February 3	Lecture	J. L. Stone
Lincolndale	February 3	Lecture	E. S. Savage
Lodi	February 3	Lecture	F. W. Kazmeier
Penn Yan	February 3–5	Lectures	R. S. Moseley
Sinclairville	February 4	Lecture	J. L. Stone
Perry	February 5	Lecture	J. L. Stone
Merrifield	February 5	Lecture	E. S. Savage
Oneonta	February 6	Lecture	M. Fairchild
Bluff Point	February 6	Lecture	E. O. Fippin
Dansville	February 6	Lecture	R. S. Moseley
Sherwood	February 7	Review Day	A. C. King L. M. Hurd M. F. Barrus
Seneca Falls	February 7	Lecture	R. S. Moseley
Merrifield	February 7	Lecture	M. F. Barrus G. W. Tailby, jr.
Derby	February 9	Lecture	H. B. Knapp
Le Roy	February 9	Lecture	R. S. Moseley
Dryden	March 9–14	Extension school	E. O. Fippin H. A. Hopper R. S. Moseley M. Fairchild
Monticello	March 9–14	Extension school	A. C. King M. F. Barrus W. G. Krum M. Fairchild

Meetings arranged by Department of Extension Teaching (continued)

Place	Time	Kind of meeting	Speaker
North Collins	March 10	Lecture	H. B. Knapp
Ovid	March 10	Lecture	F. W. Kazmeier
Lodi	March 10	Lecture	F. W. Kazmeier
Kenwood	March 13	Lecture	H. B. Knapp
Dansville	March 13	Lecture	R. S. Moseley
Odessa	March 13	Lecture	F. W. Kazmeier
Geneva	March 13	Institute workers	R. H. Wheeler
Monticello	March 14	Lecture	M. Fairchild
Palmyra	March 14	Lecture	H. B. Knapp
Newark	March 16	Lecture	C. D. Smith
Bainbridge	March 16	Lecture	John Barron
Lyons Falls	March 18	Lecture	A. E. Wilkinson
Holley	March 18	Lecture	C. D. Smith
Seneca Falls	March 21	Lecture	M. Knowlton
Almond	March 21	Lecture	H. H. Wing
Marathon	March 21	Lecture	John Barron
Horseheads	March 21	Lecture	A. C. King
Linwood	March 21	Lecture	Miss Titsworth
Unadilla	March 23	Lecture	F. W. Kazmeier
Boonville	March 23	Lecture	R. H. Wheeler
Hamburg	March 23–28	Extension school	E. O. Fippin
			J. L. Stone
			W. L. Markham
			A. P. Williams
			A. E. Wilkinson
			Paul Work
Sinclairville	March 24	Lecture	C. D. Smith
Lockport	March 24	Lecture	F. W. Kazmeier
Gardenville	March 26	Lecture	A. E. Wilkinson
Albany	March 27	Lecture	Miss Minns
Highland	March 27	Lecture	Miss Van Rensselaer
Frewsburg	March 27	Lecture	J. L. Stone
Berkshire	March 27	Lecture	F. E. Rogers
Fair Haven	March 27	Lecture	A. C. King
Red Creek	March 27	Lecture	A. C. King
Red Creek	March 30	Lecture	H. C. Chandler
Spencerport	April 1	Lecture	J. E. Rice
Lockport	April 2	Lecture	A. E. Wilkinson
Hudson F.	April 3	Lecture	Mrs. Comstock
Kenwood	April 3	Lecture	E. W. Benjamin
Herkimer	April 4	Lecture	H. E. Ross
Ithaca	April 4	Grange meeting	C. D. Smith
Harrison	April 6	Lecture	O. B. Kent
Hudson	April 7	Lecture	R. S. Moseley
Kenwood	April 10	Lecture	Paul Work
Scotia	April 11	Lecture	H. A. Hopper
Webster	April 11	Lecture	T. H. King, jr.
Ticonderoga	April 13–18	Extension school	H. A. Hopper
			H. B. Knapp
			J. H. Barron
Lockport	April 14	Lecture	C. D. Smith
Hancock	April 18	Lecture	W. G. Krum
Wolcott	April 20	Lecture	E. O. Fippin
Sherburne	April 21	Lecture	Miss Van Rensselaer
Avoca	April 24	Lecture	C. D. Smith
Sinclairville	April 25	Lecture	C. D. Smith
Port Jefferson	April 25	Lecture	A. E. Wilkinson
Newfield	April 28	Lecture	E. S. Savage
Bethel Grove	April 28	Lecture	A. A. Allen
			B. W. Shaper
Canaseraga	April 30	Lecture	C. O. DuBois
Oakfield	May 2	Lecture	J. L. Stone
Denmark	May 2	Lecture	C. D. Smith
Bethel Grove	May 7	Lecture	A. A. Allen
			B. W. Shaper
Newburgh	May 10	Lectures (2)	A. E. Wilkinson
Derby	May 11	Lecture	R. S. Moseley
Lincolndale	May 12	Lecture	C. R. Crosby
East Bloomfield	May 12	Lecture	L. H. Bailey
Rogersville	May 13	Lecture	C. O. DuBois
Freemont	May 14	Lectures (3)	C. O. DuBois
Hornell	May 14	Lecture	C. O. DuBois
Hartsville	May 14	Lectures (2)	C. O. DuBois
Dansville	May 15	Lecture	C. O. DuBois

Meetings arranged by Department of Extension Teaching (continued)

Place	Time	Kind of meeting	Speaker
Arkport	May 15	Lecture	C. O. DuBois
Hornell	May 15	Lectures (2)	C. O. DuBois
South Penn Yan	May 15	Lecture	J. L. Stone
In-a-vale	May 16	Lecture	C. O. DuBois
Little York	May 17	Lecture	Miss Nye
Newark Valley	May 19	Lecture	R. H. Wheeler J. L. Stone
Little Falls	May 21	Lecture	E. O. Fippin
Little Falls	May 22	Lecture	Miss Knowlton
Herkimer	May 23	Lecture	Miss Knowlton
Salamanca	May 17–23	Lectures	Miss Mills
Newfield	May 25	Lecture	C. H. Tuck
Kennedy's Corners	May 26	Lecture	C. W. Whitney
Canaan	May 28	Lectures (2)	W. G. Krum
Burt	May 30	Lecture	G. W. Cavanaugh
De Peyster	June 3	Lecture	H. A. Hopper
Interlaken	June 6	Lecture	E. O. Fippin
Danby	June 6	Lecture	H. C. Troy G. N. Lauman W. G. Krum
Ithaca	June 9	Lecture	Miss Van Rensselaer
Preble	June 12	Lecture	Miss Birdseye
Cuba	June 12	Lecture	C. O. DuBois
Cortland	June 12	Lecture	Miss Birdseye
Jacksonville	June 13	Lecture	G. W. Cavanaugh
Marathon	June 16	Lecture	Miss Birdseye
Wellsville	June 16	Lecture	C. O. DuBois
Buffalo	June 16	Lecture	Miss Van Rensselaer
Groton	June 19	Lecture	Miss Birdseye
East Homer	June 22	Lecture	Miss Birdseye
Margaretville	June 22	Lecture	R. H. Wheeler
McGraw	June 23	Lecture	Miss Birdseye
Utica	June 23	Lecture	Miss Knowlton
Lake Placid	June 24–27	Lectures	Miss Van Rensselaer Miss Rose Miss Fleming Miss Hunn
Otto	June 24	Lecture	C. O. DuBois
Marathon	June 25	Lecture	Miss Titsworth
Little York	June 26	Lecture	Miss Titsworth
Preble	June 27	Lecture	Miss Titsworth
Ransomville	June 27	Lecture	M. F. Barrus
Cuyler	June 29	Lecture	Miss Titsworth
Truxton	June 30	Lecture	Miss Titsworth
Derby	July 13	Lecture	B. B. Robb
Merrifield	July 16	Lecture	E. O. Fippin
Ithaca	July 17	Lecture	Royal Gilkey
Cuyler	July 27	Lecture	Miss Titsworth
Panama	July 28	Lecture	C. O. DuBois
Truxton	July 28	Lecture	Miss Titsworth
East Homer	July 29	Lecture	Miss Titsworth
Cortland	July 30	Lecture	Miss Titsworth
Kennedy	July 30	Lecture	C. O. DuBois
Groton	July 31	Lecture	Miss Titsworth
Yorktown	August 4	Lecture	E. O. Fippin
East Bloomfield	August 6	Lecture	C. R. Crosby
Frewsburg	August 8	Lecture	G. W. Cavanaugh
Derby	August 10	Lecture	K. C. Livermore
Yorkshire	August 12	Lecture	David Lumsden
Preston Center	August 12	Lecture	J. L. Stone
Columbus	August 19	Lecture	H. E. Ross
Penn Yan	August 19	Lecture	E. O. Fippin
Kelloggsville	August 20	Lecture	E. V. Hardenburg
Sauquoit	August 20	Lecture	Miss Nye
Barton	August 21	Lecture	H. A. Hopper
Greenville	August 22	Lecture	
Alfred	August 25	Lecture	R. H. Wheeler
Alfred	August 25	Lecture	R. H. Wheeler
Ellington	August 25	Lecture	G. W. Cavanaugh
Bellona	August 26	Lecture	G. W. Cavanaugh
Portland	August 27	Lecture	Paul Work
Pattersonville	September 3	Lecture	Royal Gilkey
Cato	September 4	Conference	D. J. Crosby
Fredonia	September 4	Lecture	Donald Reddick

Meetings arranged by Department of Extension Teaching (concluded)

Place	Time	Kind of meeting	Speaker
Interlaken	September 5	Lecture	W. H. Chandler
East Bloomfield	September 8	Conference	D. J. Crosby
Preble	September 9	Lecture	Miss Nye
Fillmore	September 9	Lecture	C. O. DuBois
South Wales	September 9	Lecture	W. G. Krum
Buffalo	September 9	Lecture	W. G. Krum
Ovid	September 9	Conference	D. J. Crosby
Ithaca	September 10	Lecture	Royal Gilkey Miss Van Rensselaer Miss Rose
Watkins	September 10	Conference	D. J. Crosby
Hunters Creek	September 10	Lecture	W. G. Krum
Dundee	September 10	Lecture	W. G. Krum
Moravia	September 11	Lecture	Miss Nye
Rushville	September 12	Lecture	D. J. Crosby
Cortland	September 12	Lecture	Miss Nye
Jeffersonville	September 12	Lecture	E. V. Hardenburg
Sennett	September 12	Lecture	G. W. Cavanaugh
Worcester	September 14	Conference	D. J. Crosby
Machias	September 14	Lecture	C. O. DuBois
Stamford	September 15	Conference	D. J. Crosby
Liberty	September 16	Conference	D. J. Crosby
Jeffersonville	September 16	Conference	D. J. Crosby
Monticello	September 17	Conference	D. J. Crosby
Little York	September 18	Lecture	Miss Nye
Arthursburg	September 18	Conference	D. J. Crosby
Fort Plain	September 19	Conference	D. J. Crosby
Rural Grove	September 19	Conference	D. J. Crosby
Ticonderoga	September 21	Conference	D. J. Crosby
Ellenburg Depot	September 22	Conference	D. J. Crosby
Malone	September 23	Conference	D. J. Crosby
Bath	September 23	Lecture	W. G. Krum
Lisbon	September 24	Conference	D. J. Crosby
Kirkville	September 25	Lecture	F. E. Rogers
Warsaw	September 26	Conference	D. J. Crosby

Cornell Reading-Course for the Farm

The Reading-Course for the Farm has made rapid growth during the past year. The total enrollment during the year has increased from 3884 to 5877, which is a gain of over fifty-one per cent. The interest in the discussion papers as shown by the number returned has even surpassed he rate of increase in the enrollment. During the past year 17,347 discussion papers were returned as compared with 11,156 the previous year, a gain of over fifty-five per cent. The above figures are particularly gratifying in view of the revision of the mailing list which takes place each year. If a reader has not returned a discussion paper within two years, his name is taken from the list. The list, therefore, represents those who are actually studying Reading-Course lessons and returning the discussion papers.

The number of Cornell study clubs using Reading-Course lessons for the Farm has increased to seventeen. The results attending visits to Reading-Course clubs during the past year were so encouraging that an itinerary is being arranged whereby the supervisor may visit each of the clubs organized during the past three years. It is hoped in this way to bring some of the inspiration of the College to the clubs.

Series	Number of lessons issued during year	Total number of lessons available	New readers by series	Discussion papers returned
The soil	2	3	728	2,157
Poultry	....	2	1,206	2,388
Rural engineering	.....	1	148	365
Farm forestry	1	4	128	885
The horse	1	3	334	1,531
Dairying	2	4	406	2,112
Fruit growing	2	6	709	2,882
Farm crops	1	3	436	1,277
Stock feeding	....	1	242	437
Vegetable gardening	1	3	688	2,068
Plant breeding	1	3	177	942
Country life	1	1	13	303
Total	12	34	*5,215	17,347
New readers				3,285
Old readers renewed				767
Readers continued from previous year				1,825
Total enrollment				5,877
Cornell study clubs				17

*Since many readers enroll for more than one series, the total new readers by series is greater than the number of new readers given below.

MAILING DIVISION

The Mailing Division is the central mailing agency for the distribution of all the official publications of the College. During the last three years the number of publications issued has greatly increased; modern machinery has been installed, and the permanent working force has been increased to twelve persons. The number of publications, including supplements, which the Mailing Division has handled per week for the last three years is as follows:

1911–1912	54,969
1912–1913	68,284
1913–1914	77,577

The above figures include publications issued during the year only. In addition, publications remaining from previous years have been handled. The total number of publications at the present time available for distribution is given below:

Reading-Course Lessons for the Farm.............. 34
(Discussion papers not counted)

Reading-Course Lessons for the Farm Home........	31
(Discussion papers not counted)	
Experiment Station bulletins.......	35
Experiment Station memoirs.	4
Experiment Station circulars.....	17
Extension circulars.............	8
Announcements............................	5
Rural School Leaflets......................... .	5
Farm Bureau circulars...........	4
Annual Reports.	1
Miscellaneous.................	6
Total................................ .	150

The revision of the Experiment Station mailing list has been accomplished during the past year. Three classification cards had previously been sent at intervals to persons on the Experiment Station list who had not indicated the subjects on which publications were desired. As a result of these cards a response was obtained from 25,283 persons. Those who did not return classification cards were dropped from the mailing list.

A movement has been started to insure a more general use of the publications of the College of Agriculture in the libraries of the State. From letters written to a number of libraries it was found that a general demand existed for agricultural bulletins for library use. Suggestions were requested from the Director of the New York State Library for a systematic plan of distribution. The Director of the State Library showed considerable interest in the project. An invitation was extended to the College to present the extension work in agriculture and domestic science at the annual meeting of the New York State Library Association, with particular emphasis on publications. As a result of this program, a library mailing list has been started which it is hoped will soon include a large proportion of the libraries in the State. At the suggestion of the Director of the State Library a list of the current publications of the College will be printed in *New York Libraries*, a publication of the State Education Department. In addition it is planned to correspond with each library in the State not at present on the mailing lists of the College.

Summary of itemized report of Mailing Division

The Mailing Division sends out the publications to persons on the mailing lists. It also handles requests for Experiment Station publications addressed to the College of Agriculture. The total number of

such pieces of mail received during the past year amounted to 20,998. The Mailing Division is also asked to send all publications requested in the correspondence received by the departments of the College, with the exception of the Department of Home Economics, which answers requests for Reading-Course Lessons for the Farm Home independently. The total requests for the year amounted to 47,535, as follows:

Publications	Number of requests
Experiment Station bulletins and circulars	19,924
Experiment Station memoirs	248
Reading-Course Lessons for the Farm	24,568
Farm Bureau circulars	1,049
Reports	587
Official publications of Cornell University	330
Nature Study books	171
Miscellaneous	658
Total	47,535

The labor cost, at fifteen cents per hour, amounted to $4215.18, and was distributed as follows:

Administration (supervision, mail, changes on mailing lists, sending out Experiment Station publications and the Announcer to mailing list)	$2,417.82	
Department of Extension Teaching (sending Reading-Course Lessons for the Farm to mailing list)	245.02	
Department of Home Economics (sending Reading-Course Lessons for the Farm Home to mailing list)	429.40	
Department of Rural Education (sending Rural School Leaflets to mailing list)	281.34	
Department of Extension Teaching (Cutting stencils for mailing lists and special work)	426.93	
Other departments (special work requested)	414.67	
Total		$4,215.18
Cost of second-class postage	$1,728.98	
Cost of cartage	210.47	
Cost of stamps	352.72	
Total		2,292.17
Grand total of operating expenses		$6,507.35

The following tables show, by numbers and graphically, the number of persons on the mailing lists:

County	Experiment Station publications	Reading-Course for the Farm	Reading-Course for the Farm Home	Rural School Leaflets	Total
Albany	387	94	682	2,796	3,959
Allegany	323	68	764	3,897	5,052
Broome	462	114	912	3,482	4,970
Cattaraugus	408	69	819	4,361	5,657
Cayuga	727	73	920	3,024	4,744
Chautauqua	1,146	167	1,209	4,928	7,450
Chemung	662	77	605	2,365	3,709
Chenango	430	63	709	3,271	4,473
Clinton	137	36	502	3,829	4,504
Columbia	218	57	452	3,535	4,262
Cortland	321	63	706	2,227	3,317
Delaware	320	81	555	5,589	6,545
Dutchess	392	108	652	3,461	4,613
Erie	1,096	237	1,346	10,320	12,999
Essex	137	35	451	2,532	3,155
Franklin	137	42	417	4,843	5,439
Fulton	104	24	209	1,707	2,044
Genesee	416	77	604	2,104	3,201
Greene	154	37	253	2,135	2,579
Hamilton	3	3	6	577	589
Herkimer	211	135	512	3,137	3,995
Jefferson	400	100	807	4,506	5,813
Lewis	121	136	453	2,897	3,607
Livingston	376	41	555	2,540	3,512
Madison	449	81	705	2,867	4,102
Monroe	1,263	250	1,257	7,741	10,511
Montgomery	185	40	452	2,692	3,369
Nassau	269	92	304	3,106	3,771
Niagara	479	78	652	3,972	5,181
Oneida	712	176	1,014	6,787	8,689
Onondaga	1,140	188	1,069	5,217	7,614
Ontario	562	160	706	4,113	5,541
Orange	511	106	502	5,196	6,315
Orleans	244	38	352	2,156	2,790
Oswego	503	115	819	3,622	5,059
Otsego	489	89	875	4,869	6,322
Putnam	46	11	250	1,132	1,439
Rensselaer	279	82	455	3,109	3,925
Rockland	154	62	201	1,323	1,740
Saint Lawrence	291	95	503	6,077	6,966
Saratoga	240	81	501	4,203	5,025
Schenectady	322	118	454	1,867	2,761
Schoharie	227	35	353	2,273	2,888
Schuyler	159	22	325	1,569	2,075
Seneca	242	36	506	1,734	2,518
Steuben	542	97	708	6,144	7,491
Suffolk	1,231	100	605	4,664	6,600
Sullivan	255	77	378	3,884	4,594
Tioga	398	83	603	2,201	3,285
Tompkins	874	54	1,156	2,400	4,484
Ulster	411	146	651	4,536	5,744
Warren	97	25	277	1,808	2,207

County	Experiment Station publications	Reading-Course for the Farm	Reading-Course for the Farm Home	Rural School Leaflets	Total
Washington	256	52	455	3,161	3,924
Wayne	481	57	680	3,293	4,511
Westchester	542	205	661	2,791	4,199
Wyoming	313	73	501	2,156	3,043
Yates	216	38	453	1,684	2,391
Greater New York	1,813	978	2,598	19,000	24,389
Total	25,283	5,877	37,081	217,410	285,651

County	Total
Albany	3,959
Allegany	5,052
Broome	4,970
Cattaraugus	5,657
Cayuga	4,744
Chautauqua	7,450
Chemung	3,709
Chenango	4,473
Clinton	4,504
Columbia	4,262
Cortland	3,317
Delaware	6,545
Dutchess	4,613
Erie	12,999
Essex	3,155
Franklin	5,439
Fulton	2,044
Genesee	3,201
Greene	2,579
Hamilton	589
Herkimer	3,995
Jefferson	5,813
Lewis	3,607
Livingston	3,512
Madison	4,102
Monroe	10,511
Montgomery	3,369
Nassau	3,771
Niagara	5,181
Oneida	8,689
Onondaga	7,614
Ontario	5,541
Orange	6,315
Orleans	2,790
Oswego	5,059
Otsego	6,322
Putnam	1,439
Rensselaer	3,925
Rockland	1,740
Saint Lawrence	6,966
Saratoga	5,025
Schenectady	2,761
Schoharie	2,888
Schuyler	2,075
Seneca	2,518
Steuben	7,491
Suffolk	6,600
Sullivan	4,594
Tioga	3,285
Tompkins	4,484
Ulster	5,744
Warren	2,207
Washington	3,924
Wayne	4,511
Westchester	4,199
Wyoming	3,043
Yates	2,391
Greater New York	24,389

Press notices

The papers of the State were reached this year, as in previous years, by means of the Announcer, which has been sent each month. Special press notices in manuscript form have also been sent to a list of two hundred and fifty papers that have requested such notices from the College. Nine special press notices were sent out relating to Farmers' Week, twenty-six on exhibits at county fairs, eight on timely notices of value to the farmer, and four on miscellaneous subjects — making a total of forty-seven.

RECOMMENDATIONS

Mailing Division.— The activities of the Mailing Division have increased during the past year by reason of the growth of the mailing lists, as shown in the tabulated forms of the mailing rooms, and additional post-office requirements for mailing second-class material. While the present addressing machinery has given satisfaction, it is coming to be inadequate to handle the increased work. There should be the most efficient machinery for addressing and duplicating letters. The Mailing Division is an important part of the informational activities of the College and should have adequate facilities. The total labor cost in the mailing rooms for the past year was $4215.18.

Lectures.—While the demand for lectures has increased during the year, as shown by the figures, the important step now is to more definitely organize this work into lecture courses of three to six lectures at a given place during the year. There should be a logical sequence in these lectures. They are closely related to the demonstrations — in many instances they are a part of them. More maintenance funds are needed for conducting this work. There is an instructor in the Department in charge of the work.

Extension schools.— The extension schools are now definitely established beyond the experimental stage. Their nature is well known. They represent a school of one week for those persons sufficiently advanced in interest and in ability to profit by such work. These schools are a part of an educational aid to the community covering the whole span of twelve months. At the school suggestions are made for cooperative tests during the spring and summer. Those who have attended the extension schools during the winter will be visited by an expert during the summer. Demonstrations will be held on their farms. Data are thus obtained for use in the following winter, when the next extension school is held. This gives an admirable opportunity for the organization in a community of such rural enterprises as cow-testing associations, cooperative buying and selling societies, credit unions, or whatever other cooperative work may seem best.

It is recommended that this enterprise be enlarged so that there will be at least four extension schools in every rural county in the State.

Experimenters' League.— The Experimenters' League has proved in a small way the need of attention to definitely conducted cooperative tests between farmers on the one hand and a properly trained expert from the College on the other. This work should be conducted with care. It requires the visit of an expert two or three times, if not oftener, during the season. Only those tests that would be of benefit to the region should be undertaken. At least two thousand farmers should be in active cooperation with the College in this way.

Reading-Courses.— The Reading-Course for the Farm has shown a large increase in registration of names of persons definitely interested in some phase of country life. There is need for the organization of groups of readers wherever this is practicable. There should be assistance to the assistant professor in charge of this work, so that he may be free to visit reading clubs throughout the State and connect their study with the library facilities of the State Education Department, with which cooperation is maintained in this work.

Railroad traveling schools.— During the past year several traveling schools have been conducted. A special car, fitted with teaching material and accompanied by two representatives of the College and one of the railroad, is moved from place to place on advertised schedules. Instruction is given to small groups, both at the car and in adjacent fields and barns. This is done during the growing period of products dealt with. In these cars only one or two subjects are presented. This is not the railroad propaganda of the years past, but is a new kind of intensive teaching. It is recommended that this work be increased.

Farmers' Week.— While Farmers' Week is established on a definitely organized basis, it is important that the program be enlarged to take in new subjects of interest and value. There should be a program on rural organizations and markets, another on rural credit and banking, and another on pure seed. In order to accomplish this there should be more funds to permit of bringing a limited number of experts on these questions, both from within and from without the State.

Undergraduate teaching.— This Department has experimented with the teaching of the subject of self-expression in relation to the training of undergraduates for extension service. The past years have proved the value of the work, so that now an assistant professor is in charge of it. The course is not one in elocution, but it aims to develop the individual in capacity to procure, analyze, and adequately express information of value on country-life subjects. The technical work of the extension service is intimately woven into the course. The facilities for this teaching should be increased.

The assistant professor should be made a full professor, with a sufficient number of assistants to adequately conduct the work.

Farm visits.— In years past, much importance has been attached to visits by representatives of the College to individual farms where there were problems of importance to the community. During the past four or five years this work has not received the attention that its importance deserves. It is recommended that provision be made for a larger number of these visits, in cooperation with farm bureaus and other properly designated state agencies, to the end that expert assistance may be given to individual farmers in the case of problems that are pertinent to the region concerned.

Demonstrations.— More clearly every day is it shown that extension teaching, like other teaching, is more effective when intimately related with demonstrations. It is important that demonstrations in the growth and care of farm plants and animals be conducted. These require the attention of experts. While there are a few at the College, the number should be increased to the end that the farm bureaus and other agencies in the State may have proper assistance in teaching improved methods in a practical way on the farm.

Division of the State.— As was pointed out in the Annual Report of last year, the most pressing need in the organization of the extension work of the College is to have sufficient assistance so that the State may be districted into at least four main divisions — north east, south, and west. For each division there should be at the College one person whose duty it would be to see that all extension enterprises of the College reach that section of the State in a proper way. It should be done in cooperation with those state agencies properly concerned with such work. There is need of more information as to regional problems. The soil and farm management surveys are helpful as far as they go, but the State as a whole is being covered in this way too slowly. Efficient extension work is based on knowledge of local needs. Such information would be gained more rapidly by the creation of these divisions, and the assignment of a person to take charge of each.

A further reason for such a division lies in the necessity of bringing the needs of the region to the attention of experts at the College along lines that will be efficient in the field through cooperation, rather than by a mere projection of departmental activity of the College. For example, Long Island presents a large number of problems, most of which should be welded into a project that should require the attention of experts. This in turn requires the consolidation of the activities of the several departments concerned at the College, so that the persons in the region concerned have the necessary assistance without the confusion caused by College experts acting separately.

For the coming year it is recommended that two persons be appointed to begin such work.

General extension service.— In these recommendations larger questions are involved than those of a particular department. Therefore it is not out of place to mention the need of extension service in such lines of work as plant breeding, agricultural chemistry, farm mechanics, and other phases not now represented in the extension service. As a beginning, one person should be placed in each department where extension service is needed. Promptly following this step there should come an increase of one to two persons in each phase of extension service of the College. The State is so large, and the agricultural interests are so important, that to hesitate in this means to hesitate in promoting the economic and social welfare of the rural population of this State.

Cooperation.— There are so many state agricultural agencies now at work, and there is so much work which is yet undone and for which there is neither adequate plan nor facilities, that it is imperative that the closest cooperation and the best of mutual understanding be maintained with all present agricultural agencies. There is much to be commended in the present harmonious relationship that exists, largely because of the ability of the several persons concerned to work together. But it is not wise to let such important work rest on personalities. There should be a well-thought-out and carefully executed plan that will coordinate all legitimate agricultural agencies for the betterment of country life in the State.

C. H. TUCK,

Professor of Extension Teaching.

OCTOBER, 1913 BULLETIN 336

CORNELL UNIVERSITY
AGRICULTURAL EXPERIMENT STATION OF
THE COLLEGE OF AGRICULTURE
Department of Dairy Industry

DISTRIBUTION OF MOISTURE AND SALT IN BUTTER

By E. S. GUTHRIE and H. E. ROSS

ITHACA, NEW YORK
PUBLISHED BY THE UNIVERSITY

CORNELL UNIVERSITY

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DISTRIBUTION OF MOISTURE AND SALT IN BUTTER

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The Internal Revenue Office of the United States Treasury Department has ruled that butter containing sixteen per cent or more of water is adulterated. Information concerning the variation of moisture in butter is very necessary, for there is a possibility that this law may be unjustly executed. It is desirable that the Government, the maker, and the consumer should have some knowledge of the variation of salt in butter; but, so long as water is the constituent that is regulated by the Government, naturally more attention should be paid to that. The purpose of the present bulletin is merely to show the variation of moisture and salt in butter as found on the market, not to consider the factors that control the incorporation of these two constituents.

Most of the packages from which the samples used in these experiments were taken, were sent to the Educational Judging of Dairy Products conducted by the Department of Dairy Industry at Cornell University. The samples came from churnings in different parts of the State, which were sent immediately to market, and they were in every way representative of the butter that is on the various markets.

The samples were taken with a butter-trier and were placed in dry glass bottles. No experiments were made in order to determine the proper method of sampling. At the outset the assumption was that the trier method was as good as any, if not the best, for sampling both soft butter from the churn and hard butter in the refrigerator. Each time that a plug of butter was put into the bottle, all the unincorporated moisture, so far as possible, was delivered with it. The average size of the samples was about three ounces. Most of the samples consisted of three plugs of butter taken so near together that only one hole was left in the package. In many instances, as in case of a thirty- or a sixty-pound tub, the sample comprised only one plug.

The analyses for moisture were all run in duplicate by the gravimetric method. In every reported analysis the duplicate checked to within .1 of 1 per cent. The salt analyses were made by the silver-nitrate method, which is commonly used in testing laboratories and in creameries. All the titrations were carefully checked.*

* The authors are indebted to C. B. Haviland and I C. Carpenter, senior students in agriculture, and Ivan McKellip, a graduate student in agriculture, for their assistance in the analytical work.

According to Lee, Hepburn, and Barnhart * there is a variation in the water content, ranging from .1 to 1 per cent, between different samples representing the same butter. The average variation is about .5 of 1 per cent. These figures are not exactly comparable to the results recorded in this bulletin, since each sample consisted of several portions taken throughout the churning, whereas each sample in this work was from a single spot. Nevertheless, in a general way, comparison may be made. It is noticeable in these experiments that in several cases there was a far greater variation.

ANALYSES OF SAMPLES

PACKAGE 1

This package contained five pounds. The body was almost perfect. The box was about ten inches long, five inches wide, and approximately three inches deep. The samples were taken as follows: a, b, d, and e were taken near the corners of the box, about an inch of butter being left between the sample hole and the box; sample c was taken from the middle of the package. This butter contained no salt.

ANALYSIS

Sample	Water
a	12.47
b	12.76
c	12.72
d	12.94
e	13.13

PACKAGE 2

The condition of the body was good The samples were taken from the Simplex churn No. 9, which has a capacity of 900 pounds. At the time when these samples were taken the churn contained about 900 pounds of butter. The location from which each sample was taken is definitely known.

ANALYSIS

Sample	Salt	Water
a	3.84	13.64
b	3.55	13.87
c	3.31	13.47
d	3.22	13.49
e	3.93	13.66
f	3.50	13.84

* Illinois Agricultural Experiment Station. Bulletin 137.

Sample	Salt	Water
g	3.55	13.60
h	3.37	13.52
i	3.26	13.52
j	3.46	13.01
k	3.52	13.15
l	3.54	13.86
m	3.42	13.42
n	3.33	13.10

PACKAGE 3

This package was a five-pound tin pail. The condition of the body showed that the butter was over-worked. The water seemed to be well incorporated. Each sample consisted of three full triers, taken so close together that only one hole was left. The samples were taken about three fourths of an inch from the side of the pail, and were about three fourths of an inch apart.

Analysis

Sample	Salt	Water
a	2.83	13.98
b	2.81	14.40

PACKAGE 4

This butter was in a thirty-pound tub. The body was rather leaky. Each sample consisted of a single trier extending from the top to the bottom of the package. The distance between the place where the sample was taken and the side of the tub was about one inch, and the distance between samples was about one inch. This method of sampling left a row of holes extending about halfway around the tub.

Analysis

Sample	Salt	Water
a	2.74	14.42
b	2.66	14.62
c	2.86	15.08
d	2.58	14.31
e	2.64	14.41
f	2.66	14.28
g	2.50	13.46
h	2.58	14.19
i	2.73	14.36

PACKAGE 5

This package was a five-pound box similar to package 1. The condition of the body was fair. The samples were taken about one inch from the edge and were about two and one half inches apart.

ANALYSIS

Sample	Salt	Water
a	4 67	12 68
b	4.81	13.34

PACKAGE 6

There were four prints in this package. Each sample consisted of three triers extending lengthwise through the print.

ANALYSIS

Sample	Salt	Water
a	2.94	11.53
b	3.03	11.47
c	2.94	11.27
d	3.13	11.51

PACKAGE 7

This butter was in a five-pound pail. The body showed that the butter was over-worked and greasy. The samples consisted of three full triers extending from the top to the bottom. They were taken about one half inch from the edge and one inch apart. This package contained no salt.

ANALYSIS

Sample	Water
a	14.26
b	14.43

PACKAGE 8

This package was a ten-pound tub. The body was fair. Each sample consisted of one plug extending from the top to the bottom of the tub. The samples were taken about one inch from the edge of the tub and about one inch apart. The bottle containing sample g was broken.

ANALYSIS

Sample	Salt	Water
a	1.42	12.29
b	1.40	12.29

Sample	Salt	Water
c	1 44	11.81
d	1.45	12.59
e	1.40	12.37
f	1.40	12.51
g	....	....
h	1 34	12.61

PACKAGE 9

In this package the body was fair. Each sample was taken from a single print.

ANALYSIS

Sample	Salt	Water
a	2 34	10.64
b	2.35	12.09
c	2.35	12.31

PACKAGE 10

This was a thirty-pound tub of butter. There was some unincorporated moisture. Each sample consisted of one trier extending the entire depth of the tub. The samples were taken from a straight line across the package, about one inch apart. Samples a and g were taken about one fourth of an inch from the edge of the butter.

ANALYSIS

Sample	Salt	Water
a	3.00	11.45
b	3.11	11.52
c	3.14	11.47
d	2.91	11.27
e	3.03	10 94
f	2.98	11 53
g	3.01	11.76

PACKAGE 11

This was a five-pound pail of butter. The body showed a slightly over-worked condition but otherwise was excellent. The samples were taken about one inch from the edge of the butter, with about three inches between samples.

ANALYSIS

Sample	Salt	Water
a	3.43	14.90
b	3.42	14.50

PACKAGE 12

This was a sixty-pound tub of butter. There seemed to be an excessive amount of unincorporated moisture. The samples were taken in a straight line across the middle of the tub. Each sample consisted of a full trier extending the entire depth of the package. Samples a and f were taken about two inches from the edge of the butter. The distance between the samples was less than two inches.

ANALYSIS

Sample	Salt	Water
a	1.42	14.09
b	1.57	14.55
c	1.48	14.16
d	1.57	14.25
e	1.49	14.46
f	1.59	14.28

PACKAGE 13

This was a thirty-pound tub of butter. The moisture was apparently well incorporated. Samples a and c were taken about two inches from the edge of the butter. The distance between samples was a trifle over two inches.

ANALYSIS

Sample	Salt	Water
a	1.56	12.09
b	1.54	11.66
c	1.50	11.46

PACKAGE 14

In this package of two prints the water seemed to be well incorporated.

ANALYSIS

Sample	Salt	Water
a	1.76	14.03
b	1.79	14.92

PACKAGE 15

This package was a thirty-pound tub. The moisture seemed to be poorly incorporated. Sample a consisted of a trier of butter taken horizontally about two inches from the bottom, crossing the middle of the

tub. Sample b was taken in the same manner about eight inches above sample a.

ANALYSIS

Sample	Water
a	13.40
b	12.77

PACKAGE 16

This package was a thirty-pound tub. The body showed a very leaky condition. Sample a consisted of a single trier of butter taken horizontally about two inches from the bottom, crossing the middle of the tub. Samples b, c, and d were taken above in a similar manner, there being a space of about one inch between them. Samples e and f consisted of a single trier of butter extending the full depth of the tub. Sample e was taken about one inch from the edge of the butter in the vertical position. Sample f was taken toward the middle of the tub from sample e, leaving a space of about two inches between the holes where the samples were taken.

ANALYSIS

Sample	Salt	Water
a	3.21	14.46
b	3.26	14.08
c	3.33	14.02
d	3.08	13.48
e	2.64	13.41
f	3.13	14.30

PACKAGE 17

This package was a thirty-pound tub. The body showed that the moisture was well incorporated. Samples a, b, c, and d consisted of a single trier of butter extending horizontally and crossing the middle of the tub. Sample a was taken about one inch from the bottom, sample b about one inch above sample a, sample c about one inch above sample b, and sample d about three inches above sample c. Sample e was a trier of butter extending the full depth of the tub. It was taken about one inch from the edge of the butter.

ANALYSIS

Sample	Salt	Water
a	2.15	13.36
b	1.99	13.22
c	2.32	12.67
d	2.30	13.02
e	2.09	12.99

PACKAGE 18

This was a thirty-two-pound tub of butter. The moisture was well incorporated. Six of the samples were taken in a row extending across the tub. The last three were taken promiscuously. Each sample consisted of three triers, making one hole and extending the full depth of the tub. The distance between samples was about one inch.

ANALYSIS

Sample	Salt	Water
a	1.21	13.33
b	1.20	13.66
c	1.31	13 59
d	1.26	13.32
e	1.40	13.91
f	1.21	13 41
g	1.31	13.46
h	1.21	13.54
i	1.26	13.44

PACKAGE 19

These samples were taken promiscuously throughout one large churning in the Simplex churn No. 9. The body was fair.

ANALYSIS

Sample	Salt	Water
a	1.62	14.18
b	1.79	13.49
c	1.52	13.47
d	1.43	13.52
e	1.73	14.13
f	2.09	14.14
g	1.41	13.69
h	1.92	13.84
i	2.01	13.85
j	1.56	13.97
k	1.49	14.34
l	1.55	14.35

PACKAGE 20

This package was a thirty-pound tub. The body was good. Each sample consisted of a full trier of butter extending the entire depth of

the tub. The samples were taken in a row across the middle of the tub. There was a space of about one inch between samples a and f and the edge of the butter, and the same distance between the samples.

ANALYSIS

Sample	Salt	Water
a	1 55	12.27
b	0 97	10 81
c	0 97	11 66
d	1 05	11.67
e	1.18	11.58
f	0.89	11.61

PACKAGE 21

Packages 21, 22, and 23 each contained about three pounds of butter. The body was poor and the workmanship was of low grade in all three packages. The samples were taken promiscuously throughout each package.

ANALYSIS

Sample	Salt	Water
a	3.33	10.90
b	3.15	11.50
c	2.63	8.37
d	2.63	10.90

PACKAGE 22

ANALYSIS

Sample	Salt	Water
a	1.40	10.47
b	1.22	10.90
c	1.40	10.90
d	1.40	11.50
e	1.05	12.70

PACKAGE 23

ANALYSIS

Sample	Salt	Water
a	1.57	8.61
b	1.75	8.48
c	1.57	8.63
d	1.75	8.16

PACKAGE 24

This package of ten pounds was in a ten-pound tub. The samples were taken from a straight line extending across the middle of the tub.

ANALYSIS

Sample	Salt	Water
a	1.75	15 86
b	......	11.98
c	1.40	11.07
d	1.40	11.97
e	1.45	11.61

PACKAGE 25

This package was a five-pound box. Sample a was taken from the middle, sample b near one edge, sample c in one corner, sample d near the opposite edge from sample b, and sample e in the diagonally opposite corner from sample c.

ANALYSIS

Sample	Salt	Water
a	1.57	13.55
b	1.40	10.79
c	0.08	10.56
d	1.22	10.02
e	1.05	10.18

PACKAGE 26

This was a ten-pound tub of butter. Sample a was taken near one edge, sample b toward the middle, sample c near the middle, sample d opposite sample b, and sample e opposite sample a.

ANALYSIS

Sample	Salt	Water
a	2.45	11.22
b	2.10	9.15
c	2.10	9.88
d	2.28	10.40
e	2.45	9.48

PACKAGE 27

This was a round five-pound box of butter. The samples were taken in the same manner as were those in package 26.

ANALYSIS

Sample	Salt	Water
a	3.68	11.44
b	3.68	12.19
c	3.68	10.95
d	3.51	11.50
e	3.36	10.95

PACKAGE 28

This butter was in a five-pound tin pail. The samples were taken in the same manner as were those in package 26.

ANALYSIS

Sample	Salt	Water
a	3.15	13.48
b	3.36	13.78
c	3.36	13.38
d	3.36	13.97
e	3.35	13.58

PACKAGE 29

This butter was in a five-pound earthen jar. The samples were taken in a manner similar to that used with package 26.

ANALYSIS

Sample	Salt	Water
a	1.75	12.77
b	1.57	12.70
c	1.57	12.68
d	1.57	12.75
e	2.28	10.78

PACKAGE 30

This package was a five-pound wooden box. Sample a was taken from one corner, sample b toward the middle, sample c opposite sample b,

sample d in the diagonally opposite corner to sample a, and sample e near the middle.

ANALYSIS

Sample	Salt	Water
a	1.75	11.66
b	1.75	11.93
c	1.75	11.98
d	1.75	11.17
e	1.75	11.96

PACKAGE 31

This package was a twenty-pound tub. Sample a was taken near one edge, sample b from the opposite edge, sample c toward the middle from sample a, sample d from the middle, and sample e toward the middle from sample b.

ANALYSIS

Sample	Water
a	12.28
b	12.40
c	12.73
d	12.55
e	13.03

PACKAGE 32

The butter represented in packages 32 to 51 was made in a hand churn. The amount of butter made at each churning was about twelve pounds. The methods were comparable to those used in careful farm practice. When the butter was sampled it was spread out on the worker and each sample was taken from a single spot. The distance between samples was about five inches.

ANALYSIS

Sample	Salt	Water
a	3.09	12.53
b	3.06	12.55
c	2.98	12.66
d	3.11	12.54
e	2.96	12.59

PACKAGE 33

ANALYSIS

Sample	Salt	Water
a	3.51	12.64
b	3.28	12.84
c	3.60	12.77
d	3.25	12.58
e	3.71	12.74

PACKAGE 34

ANALYSIS

Sample	Salt	Water
a	2.93	12.13
b	3.39	12.48
c	3.24	12.01
d	3.23	12.10
e	3.42	12.25

PACKAGE 35

ANALYSIS

Sample	Salt	Water
a	1.95	12.49
b	1.99	12.53
c	2.18	12.43
d	1.97	12.40
e	2.27	12.67

PACKAGE 36

ANALYSIS

Sample	Salt	Water
a	3.58	12.61
b	3.64	12.80
c	3.62	12.62
d	3.57	12.36
e	3.56	12.66

PACKAGE 37

ANALYSIS

Sample	Salt	Water
a	3.52	12.70
b	3.46	12.45
c	3.32	12.33
d	3.43	12.35
e	3.44	12.37

PACKAGE 38

ANALYSIS

Sample	Salt	Water
a.	3.29	12.24
b.	3.25	12.90
c.	3.30	12.79
d	3.24	12.92
e.	3.26	12.69

PACKAGE 39

ANALYSIS

Sample	Salt	Water
a.	4.00	12.64
b.	3.99	12.68
c.	4.05	12.85
d	3.96	12.53
e.	4.10	12.69

PACKAGE 40

ANALYSIS

Sample	Salt	Water
a.	3.21	12.53
b	3.05	12.39
c.	3.14	12.22
d.	3.21	12.40
e	3.07	12.44

PACKAGE 41

ANALYSIS

Sample	Salt	Water
a.	2.06	13.46
b.	1.89	13.20
c.	1.92	13.38
d.	2.01	13.83
e.	1.88	13.33

PACKAGE 42

ANALYSIS

Sample	Salt	Water
a.	2.89	12.66
b.	2.84	12.75
c.	2.83	12.84
d.	2.83	12.88
e.	2.93	12.86

PACKAGE 43

ANALYSIS

Sample	Salt	Water
a	3.05	12.73
b	3.09	12.84
c	3.02	12.60
d	3.13	12 81
e	3.10	12.99

PACKAGE 44

ANALYSIS

Sample	Salt	Water
a	1.81	13.84
b	1.73	13.29
c	1.83	13.42
d	1.76	13.35
e	1.71	13.25

PACKAGE 45

ANALYSIS

Sample	Salt	Water
a	2.76	12.79
b	2.75	12.76
c	2.73	12.76
d	2.60	12.32
e	2.82	12.86

PACKAGE 46

ANALYSIS

Sample	Salt	Water
a	2.09	13.55
b	1.90	12.85
c	2.02	13.17
d	1.90	13.04
e	1.95	13.10

PACKAGE 47

ANALYSIS

Sample	Salt	Water
a	3.02	12.80
b	3.08	12.92
c	3.09	12.89
d	3.00	12.84
e	3.12	12.87

Package

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ANALYSIS

	Salt	Water
	2.86	12.77
	2.88	12.73
	2.75	12 76
	2.79	12.82
	2.88	12.83

ANALYSIS

	Salt	Water
	2.77	13.37
	2.61	13.03
	2.55	12.93
	2.65	13.06
	2.77	13.17

ANALYSIS

	Salt	Water
	3.28	13.93
	3.20	13.92
	3.23	14 05
	3 31	14.07
	3.24	14.05

ANALYSIS

	Salt	Water
	3.26	13.58
	3.19	13.48
	3.13	13.10
	3.15	13.62
	3.22	13.24

MOISTURE TABLE

Package	Number of samples from package	Greatest difference between two adjacent samples	Greatest difference between any two samples	Smallest difference between two adjacent samples	Smallest difference between any two samples
1	5	29	66	04	04
2	14	71	86	00	00
3	2	42	42	42	42
4	9	82	1 62	10	01
5	2	.66	.66	66	66
6	4	24	26	06	02
7	2	17	.17	17	17
8	7	.78	80	00	00
9	3	1 45	1 67	22	22
10	7	59	82	.05	.01
11	2	40	40	40	40
12	6	46	46	.09	03
13	3	43	63	20	20
14	2	89	89	89	89
15	2	63	63	63	63
16	6	89	1 05	06	06
17	5	55	69	03	.03
18	9	.59	.59	05	.01
19	12	69	88	01	.01
20	6	1 46	1 46	.01	.01
21	4	3 13	3 13	60	.00
22	5	1 20	2 23	00	.00
23	4	47	47	13	.02
24	5	3 88	4 79	36	.01
25	5	2 76	3 53	.16	.16
26	5	2 07	2 07	.52	33
27	5	1 24	1 24	55	.00
28	5	59	59	.30	.10
29	5	1 97	1 99	02	02
30	5	81	81	05	02
31	5	48	75	12	12
32	5	12	13	02	01
33	5	20	26	07	.03
34	5	47	47	09	03
35	5	27	.27	03	.03
36	5	30	44	18	01
37	5	.25	.37	02	02
38	5	66	68	11	02
39	5	32	.32	04	.01
40	5	18	.31	04	.01
41	5	50	.63	.18	.05
42	5	.09	22	.02	.02
43	5	24	39	11	.03
44	5	.55	.59	07	.04
45	5	.54	.54	00	.00
46	5	.70	.70	06	.06
47	5	.12	.12	03	.02
48	5	06	.10	.01	.01
49	5	34	44	.10	.03
50	5	13	.15	.01	.00
51	5	52	.52	.10	.04

SALT TABLE

Package	Number of samples from package	Greatest difference between two adjacent samples	Greatest difference between any two samples	Smallest difference between two adjacent samples	Smallest difference between any two samples
1	5	...	....	..	.....
2	14	.71	.71	.02	.00
3	2	.02	.02	02	02
4	9	.28	.36	02	00
5	2	.14	.14	14	.14
6	4	.19	.19	.09	.00
7	2	......	.....	....	....
8	7	.05	.11	.00	.00
9	3	.01	.01	.00	.00
10	7	23	.23	03	.01
11	2	01	01	.01	.01
12	6	15	17	.08	.00
13	3	04	.06	02	.02
14	2	03	.03	03	03
15	2		...	.....	......
16	6	.49	.69	.05	.05
17	5	33	.33	.02	.02
18	9	19	20	.01	.00
19	12	68	.68	.06	01
20	6	58	66	00	.00
21	4	52	70	00	.00
22	5	35	35	00	.00
23	4	18	18	.18	.00
24	5	05	35	.00	.00
25	5	1.32	1 49	.17	.17
26	5	.35	35	.00	00
27	5	.17	32	.00	.00
28	5	21	.21	00	.00
29	5	.71	71	.00	.00
30	5	.00	.00	.00	.00
31	5	...	.	..	....
32	5	.15	15	.03	.02
33	5	.46	.46	.23	03
34	5	.46	49	01	.01
35	5	30	32	.04	.02
36	5	.06	.08	.01	.01
37	5	.14	20	.01	.01
38	5	.06	06	02	.01
39	5	.14	.14	.01	01
40	5	.16	.16	.07	.00
41	5	.17	.18	.03	01
42	5	10	10	.00	00
43	5	11	11	.03	.01
44	5	.10	.12	.05	.02
45	5	.22	.22	01	.01
46	5	.19	.19	.05	.00
47	5	.12	.12	.01	.01
48	5	13	.13	.02	.00
49	5	16	.22	.06	.00
50	5	.08	.11	.03	01
51	5	.07	.13	.02	.02

SUMMARY

1. Of the fifty-one packages, nine, or 17.6 per cent, showed a difference of one per cent or more of moisture in adjacent samples, and in eleven packages, or 21.6 per cent, there was a difference of one per cent or more between the lowest and the highest moisture tests.

2. Of the packages 54.9 per cent showed a difference of five tenths per cent of moisture or over in adjacent samples. There was a difference of five tenths per cent or more of moisture between the lowest and the highest moisture test in 60.8 per cent of the packages.

3. In 36.2 per cent of the packages there was a difference of two tenths per cent of salt in adjacent samples, and 46.8 per cent of the packages contained a difference of two tenths per cent salt between the lowest and the highest tests.

4. There were four instances of adjacent moisture tests being the same, and in seven packages there were two or more samples that tested the same.

5. In twelve packages adjacent salt tests were the same, and in twenty-two packages there were two or more samples that were the same in salt content.

6. Poorly made butter varied slightly more in moisture and salt than did well-made butter.

CONCLUSION

In order to get an approximate test of the moisture in butter, a sample containing only a few portions of butter may be used; but if the legal limit has been reached and the exact composition is wanted, the sample must consist of many portions taken from different parts of the package.

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AGRICULTURAL EXPERIMENT STATION OF

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Department of Dairy Industry

THE BABCOCK TEST
WITH SPECIAL REFERENCE TO TESTING CREAM

By H. E. ROSS and T. J McINERNEY

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THE BABCOCK TEST
WITH SPECIAL REFERENCE TO TESTING CREAM

H. E. Ross and T. J. McInerney

(*Received for publication August 1, 1913*)

The Babcock test is a test for the percentage of fat in milk and milk products. The test was invented by Dr. S. M. Babcock of the University of Wisconsin, and a description of it was first published in the report of the Agricultural Experiment Station of the University of Wisconsin for the year 1890.

Since milk is usually considered valuable according to the percentage of fat that it contains, the use of the Babcock test has greatly stimulated the business of dairying. This result has been brought about in four ways, as follows:

1. The test has provided a more equitable basis for payment for milk at butter and cheese factories.
2. It has been of great aid in the detection of fraud, such as the watering and skimming of milk.
3. It has enabled the dairyman to discover the most profitable cows in his herd.
4. It has enabled the dairy manufacturer to detect, and thereby to prevent, losses in his business.

While the Babcock test is simple and accurate, yet the operator must always bear in mind that the test is a delicate one and must be treated as such. Any carelessness in method or any inattention to details is likely to cause unsatisfactory and inaccurate results.

TESTING WHOLE MILK

Mixing the sample

The sample to be tested should be thoroughly mixed before it is measured out. Mixing is done by shaking the vessel in which the milk is contained, or, better still, by pouring the milk from one vessel into another. The fat in milk is lighter than the other constituents and soon rises to the surface. Unless great care is exercised an unfair sample will be taken. If the sample is an old one, such as a composite sample, it should be heated to a temperature of not over 85° F. in order to soften the fat. The sample should not be heated above 85° F., since the fat is likely to separate in the form of an oil and when so separated it is impossible to remix it evenly throughout the sample. If the cream adheres to the

inside of the bottle, a brush such as a test-bottle brush will be found useful in loosening it.

Effect of temperature on the quantity of milk taken for the Babcock test

It is usually best to have the temperature of the milk from 60° to 70° F.; however, the temperature of the milk within reasonable limits will not affect the test. This is because the coefficient of expansion of the milk is not high enough to appreciably affect the amount measured by the pipette. This fact is shown in the following table:

TABLE 1. EXPERIMENTS SHOWING RESULTS OF TESTS OF WHOLE MILK, WHEN SAMPLES WERE TAKEN AT DIFFERENT TEMPERATURES

Experiment	Percentage of fat						
	50° F.	65° F.	80° F.	95° F.	110° F.	125° F.	140° F.
1	4.1	4.1	3 9	4.1	3.9	3.9	3.9
2	3 4	3 4	3.3	3 3	3.2	3.2	3.2
3	4.8	4 7	4.6	4.6	4.6	4.6	4.6
4	4.0	3.9	3.9	4.0	3 9	3.9	3.9
5	4 2	3 9	4.0	4.1	. .	4 1	4.1
6	4 1	4.1	3.9	4 0	4.0	4 1	3.9
7	4.9	4.8	4.6	4 7	4 6	4.6	4.7
8	5.2	5.1	5.0	5 1	5.1	4.9	4.9
9	4.2	4.2	4 2	4.2	4.2	4.2	4.3
10	4.3	4.4	4 4	4.3	4 3	4.2	4.3
11	4.5	4.5	4.5	4.4	4.4	4.4	4.4
12	4.3	4 3	4 4	4.4	4.4	4.3	4.4
13	5.0	4.9	5.0	4.9	5.0	4.9	5.1
14	3.7	3.7	3.7	3.7	3.8	3.7	3.8
15	5 6	5 6	5.5	5 6	5.6	5.5	5.5
16	7.0	6.9	6 9	6.9	7.1	6.9	6.9

Measuring the sample

The instrument used in measuring the milk for the test is called a pipette (Fig. 1). It has only one graduation, 17.6 cubic centimeters, equivalent to 18 grams. The sample is measured by drawing the milk above the graduation and then placing the index finger over the end of the pipette. By carefully releasing the finger the column of milk can be lowered until the bottom of the meniscus is on a level with the 17.6-cc. mark on the pipette. It is absolutely necessary that the mark on the pipette be held on a level with the eye, so as to show when the column of milk is on a level with the mark. The milk is then transferred from the pipette to the test bottle. The pipette and the test bottle

should be slanted as shown in Fig. 2, so that the milk will run down the bottle neck and not be forced out by the air coming from the bottle.

Whole-milk test bottles are of two kinds — those reading as high as 10 per cent and graduated in fifths, and those reading as high as 8 per cent and graduated in tenths. In each case the graduations give readings directly in terms of percentage, since the graduated part of the neck is made to hold a column of fat which is a definite percentage of the weight of the milk taken. It is customary to express the readings in decimal form rather than in fractional form; as, for example, 4.5 per cent rather than 4 5/10 per cent. Since each mark on the 10-per-cent bottle has a value of 1/5 per cent, this is equivalent to .2 per cent (1/5 = 2/10), and in reading 10-per-cent bottles the results are always expressed in tenths.

FIG. 1.— *A pipette*

Sulfuric acid is added to the milk in the test bottle. This is usually done by means of a special measure which has only one graduation, 17.5 cubic centimeters (Fig. 3). The purpose of adding the acid is to destroy all the milk solids except the fat, which it does by moist combustion. In this process great heat is produced. This is advantageous, since the fat must be kept in a liquid condition in order to perform the test properly. The neck of the test bottle gives percentage readings only when the fat is in a liquid condition. In adding the sulfuric acid the bottle should be slanted, the same as in adding milk.

FIG. 2.— *Putting the milk into the test bottle. The pipette is held at an angle with the test bottle, with its point against the inside of the neck*

Adding the acid

FIG. 3.—*An acid measure*

As the acid is poured in, the bottle should be revolved so that the acid will wash down any milk that adheres to the neck of the bottle. If this is not done, the milk dries on the neck of the bottle and is lost in the test; it also causes a cloudy bottle-neck and obscures the fat column when the test is completed. The acid and the milk should be thoroughly mixed as soon as the acid is added to the bottle, else portions of the sample might be charred and so lock up small particles of fat. It is well to mix the contents of the bottle for at least half a minute after all the milk has apparently been dissolved by the acid. The mixing is done by holding the bottle by the neck between the thumb

and the index finger, and giving it a rotary motion from the wrist; if an up-and-down motion is used the contents of the bottle are likely to be spilled.

The strength of the acid used is reckoned in terms of its density, which should be 1.82 to 1.83. A special instrument is used for testing the density of the acid, and, since this instrument is seldom available in a dairy or a creamery, one of the best ways of testing the acid is to actually perform a test with it and note the results. The acid should be of such a strength that it will turn the contents of the bottle to a dark brown as soon as mixed, and the mixture should turn an intense black after standing for about one minute. The best acid is colorless, yet the acid may be fairly dark and still be fit for use. The acid should never contain any undissolved material, since this is likely to rise with the fat and obscure the reading.

Whirling the sample

After the acid and the milk are thoroughly mixed, the samples are ready for whirling. The centrifuges used are of three main types (Figs.

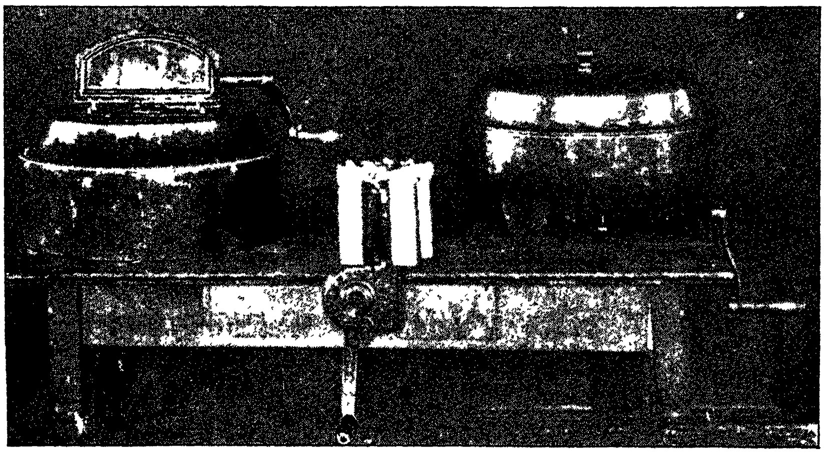

FIG. 4.— *Different styles of hand-power centrifuges*

4, 5, and 6): those driven by hand power, those driven by steam, and those driven by electricity. The steam machines are usually considered best, since with them it is easy to maintain the proper temperature during the process of whirling. The hand and electric machines should do equally as good work as the steam machines, provided a high enough temperature is maintained to keep the fat in a liquid condition. The frame of the hand machine should always be filled with hot water before the bottles are whirled. In case of the four-bottle machines, which have no

frames, the bottle cups, which are made large for that purpose, should be filled with hot water. Great care should be taken to have the machines balanced; by this is meant that for every bottle on one side of the machine there should be a bottle on the opposite side. The machines should also be well oiled, especially those driven by steam, which, because of the heat, soon dry out.

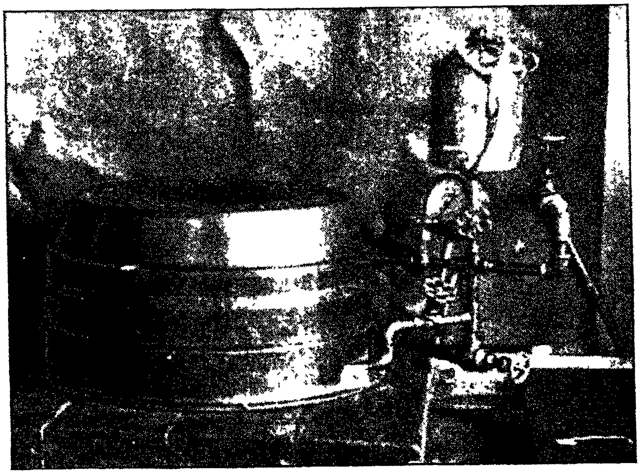

FIG. 5.— *A steam-power centrifuge*

The sample is whirled for five minutes and then filled with hot water to the base of the neck, then the sample is whirled for two minutes and hot water is again added so as to bring the fat within the graduated part of the neck. The sample is then whirled for one minute in order to bring

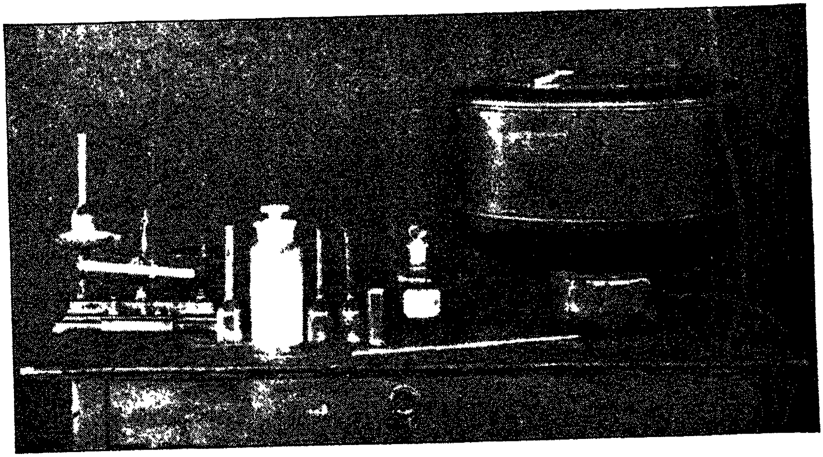

FIG. 6.— *Electric power machine, scales, acid, and glassware for the Babcock test*

all the fat into the graduated neck. Some operators of the Babcock test make two separate runs instead of three, filling the bottles to within

the graduated neck after the first run. While this may give fairly good results, yet it is better to make three separate runs as indicated above and fill to the base of the neck the first time. This washes the fat free from any sediment, and gives a clearer reading than would otherwise be obtained.

Reading the sample

The sample should be read at once, before the fat column has had time to cool. In reading, the bottle should be held between the thumb and the index finger, and the fat column should be on a level with the eye so that it may be seen when the top and the bottom of the fat column are on a level with any given mark. The fat column in a whole-milk bottle is not large enough to be greatly affected by temperature unless it is extremely hot or cold. This is shown in the following table:

TABLE 2. EXPERIMENTS SHOWING THE EFFECT OF TEMPERATURE ON THE FAT COLUMN OF A WHOLE-MILK BOTTLE

Experiment	Percentage of fat		
	When taken from machine	At 146° F.	At 100° F.
86	3 8	3.8	3 8
87	3 8	3.8	3.8
88	4.5	4.5	4.5
90	4.8	4 8	4.7
91	4.2	4.2	4.2
92	3.9	4.0	3.9
93	3.7	3 7	3.7
94	3.7	3 8	3.6
95	4.6	4 6	4.5
96	4.5	4.5	....
97	4 0	4.0	4.0
98	4.4	4.4	....
99	3 4	3.4	3.4
101	4.2	4.2	4.2

With a steam centrifuge the temperature may be extremely high and thus the reading may be slightly increased. This danger may be avoided by allowing the bottles to stand for a minute at room temperature before reading. There is greater danger of reading the fat column at too low than at too high a temperature. It does not take long for the fat column to harden, and if the room is at all cold it is safer to set the test bottles in water at about 140° F., having the water come above the fat column

in the bottle. The extreme points of the column should be included in the reading, since this method makes up very closely for minute particles of fat which are not brought to the surface during the process of testing.

There are two methods of reading the percentage of fat in the neck of the bottle. The first is to obtain the difference between the bottom and the top of the fat column; if, for example, the bottom of the fat column rests on the 1.5-per-cent mark and the top of the column on the 5.2-per-cent mark, the percentage of fat is 3.7 ($5.2 - 1.5 = 3.7$). The second method of reading the percentage of fat is to count the whole-percentage and the tenth-percentage marks covered by the fat column. Some operators make use of dividers in reading the fat column. The exact space covered by the fat column is obtained, and one point of the dividers is placed on the zero mark and the other point against the graduated mark. The latter point will indicate the percentage of fat. There is no objection to this method, provided the fat column is never measured when it is above or below the graduations on the neck of the bottle. This is often done, yet there is no certainty that the space above or below the graduations is of the same size as it is within the graduations; in fact, the space above or below the graduated part of the neck is usually larger than is the graduated part of the neck. It is, then, perfectly easy to see the inaccurate results that may be obtained by taking a reading when the fat column is without the graduated part of the bottle neck.

Care of the bottles

As soon as all the bottles are read, they should be emptied. If allowed to stand until they become cold they are more difficult to clean. The cleaning will be done much more easily if the bottles are shaken violently up and down as the contents run out. A viscous sediment is formed by the action of the sulfuric acid on the milk, and the hot acid helps to loosen this sediment if the bottles are well shaken. All Babcock glassware should be kept clean and bright. This can best be done by washing the glassware in hot water and washing powder, and then rinsing in hot water. If many bottles are used, a block and a top-board, such as are shown in Fig. 7, are very useful. The block has holes bored in it,

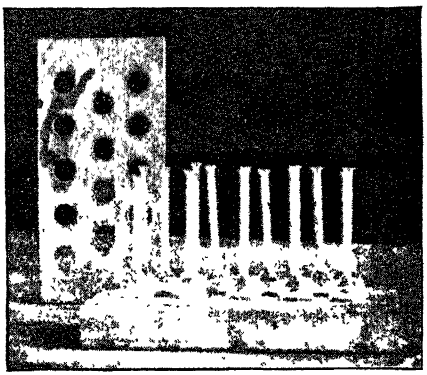

FIG. 7. — *Rack for holding test bottles. Especially useful in washing bottles*

of a size just large enough to hold the bottles, and it may be made to hold any desired number of bottles. The holes in the top-board are large enough to admit the passage of the necks through them and the board rests on the shoulders of the test bottles. In using this block and board a number of bottles can be emptied at once and the hot bottles will not burn the hands of the operator.

A completed Babcock test should fulfill the following conditions:

The fat column should be within the graduated part of the neck.

The fat column should be of a light straw-yellow color, clearly and sharply defined, and free from specks of any kind. If the fat column is pale, it indicates that the acid was too weak or too little of it was used, or that the temperature was too cold.

The material in the body of the bottle should be thoroughly dissolved.

TESTING SKIMMED MILK

Skimmed milk is milk from which a large percentage of the fat has been removed. The percentage of fat in skimmed milk depends largely on the process of separation employed, the gravity and dilution method usually being less efficient than the centrifugal separator. It is the aim of the creameryman to have his skimmed milk test no higher than .05 per cent, and as much lower as possible.

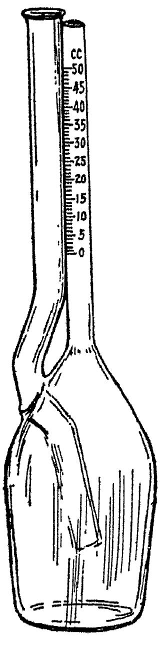

FIG. 8.—*Skimmed-milk test bottle*

For the Babcock test 17.6 cubic centimeters of skimmed milk is used. It would be impossible to test skimmed milk in a whole-milk bottle, because the percentage of fat in the neck of the bottle would be too small to be read. Because of this a bottle of very small bore is employed (Fig. 8). The opening in the graduated neck of this bottle is so small that milk and acid could not be poured through it into the bottle; therefore a funnel tube is provided, through which the milk and the acid are introduced. The funnel tube is extended to the side and the bottom of the bottle in order to minimize the possibility that fat may rise in the funnel tube rather than in the graduated tube. Skimmed-milk bottles should be placed in the machine with the funnel tubes toward the outside. When the machine is started and the bottles assume a horizontal position, the tendency is for the fat to rise in the graduated tubes rather than to lodge between the funnel tubes and the walls of the bottles.

In skimmed milk the proportion of casein to fat is greater than in whole

milk. Two to three cubic centimeters extra of sulfuric acid should be used in order to dissolve this extra quantity of casein.

The globules of fat in skimmed milk are very small, and for this reason it is difficult to bring them to the surface by centrifugal force. The bottle should therefore be whirled for periods of ten minutes, two minutes, and one minute, instead of for periods of five minutes, two minutes, and one minute as is done in the case of whole milk.

Except for using extra acid and whirling for a longer time, skimmed milk is tested in the same way as is whole milk.

The following table gives the results obtained by testing the same sample of milk in the manner in which whole milk is tested, and using extra acid and running for an extra length of time. It will be noted that in every case a higher reading was obtained when extra acid was used and the bottles were whirled for five minutes extra.

TABLE 3. COMPARATIVE RESULTS OBTAINED BY USING EXTRA ACID AND WHIRLING FOR AN EXTRA LENGTH OF TIME, IN TESTING SKIMMED MILK

Sample	Percentage of fat	
	Usual time and usual amount of acid	Two centimeters extra acid and five minutes extra time
1	.14	.1600
2	.18	.2000
3	.05	.0900
4	.10	.1200
5	.09	.1300
6	.20	.2000
7	.15	.1800
8	.01	.0200
9	.01	.0125
10	.16	.2000

TESTING FROZEN MILK

Partly frozen milk should never be sampled for testing, since a sample of such milk will not be representative. Such milk should be melted and carefully remixed before any is removed for testing, but in melting the ice a temperature of not over 85° F. should be used. Too high a temperature is likely to cause a separation of the fat in the form of an oil, and when the fat thus separates it is almost impossible to remix it evenly with the milk.

If milk is allowed to stand for any length of time before freezing, the fat will rise to the surface and form a cream line. If the cream line thus formed freezes, the ice will be rich in fat.

If milk is agitated while freezing, the ice formed will be low in fat content, since freezing tends to squeeze the fat out of the ice. This, of course, makes the liquid part of the milk richer in fat than it should be. Milk is frequently delivered to milk stations and creameries during the winter months in a partly frozen condition, and if a sample is taken for testing it will give a higher fat reading than would be shown in a mixed sample of the milk. The creameryman would therefore pay for more fat than he actually received.

The following table gives the percentages of fat found in samples of milk, in the liquid part of the milk after it was partly frozen, and in the ice:

TABLE 4. PERCENTAGE OF FAT FOUND IN MILK IN VARIOUS CONDITIONS AS TO FREEZING

Sample	Percentage of fat		
	In original milk	In partly frozen milk	
		Liquid part	Ice
1	2.9	3.1	2.6
2	3.9	4.2	3.2
3	4.7	5.0	3.7
4	1.8	1.9	1.6
5	2.3	2.5	2.2
6	4.7	5.0	4.1
7	3.7	4.4	3.0
8	3.2	3.5	3.3
9	3.6	3.8	3.2
10	4.2	4.3	3.9

TESTING CHEESE

Samples of cheese for testing may be obtained in one of two ways: one plug may be taken near the rind of the cheese, another halfway from the rind to the center, and a third at the center; or the trier may be run from the edge of the cheese into the center.

When the sample is taken it should be chopped as fine as wheat kernels. If the particles are much larger they are likely to be burned by the acid before being dissolved. The fat would be locked up in the burned particles and as a result the test would be too low.

The cheese can be chopped fine by placing the sample in a glass bottle and cutting it with a case knife. When cut fine, 3 or 4 grams of the cheese should be weighed into a cream bottle. A small quantity is used because so much acid is required in order to dissolve the curd. The sample is then made up to approximately 18 grams by adding warm or hot water. The warm water tends to soften the curd Acid is then added, a little at a time, with continual shaking until the curd is entirely dissolved. It frequently takes slightly more than the normal quantity of acid to dissolve the curd; if the sample is old and dry the operator must use his own judgment in regard to the proper quantity of acid. From this point the cheese is tested the same as is whole milk, except that glymol should be used in reading the completed test.

TESTING BUTTER

A sample of butter about twice as large as a hen's egg should be made up, parts being taken from different places in the package or the churn. This insures a representative sample. The sample should be placed in a lightning-top sample jar or in a glass-stoppered jar; a quart fruit-jar will be found useful for this purpose. The butter should then be heated, with constant stirring, until it has the consistency of thick cream. The purpose of heating and mixing is to distribute the moisture evenly throughout the sample. If the butter is melted too far it will have to be cooled before being weighed out for the test. The sample must be kept constantly stirred while cooling in order to keep the moisture evenly distributed; if this stirring is not done, the moisture will tend to collect in the center and an accurate test cannot be made. Three or four grams of the prepared sample is weighed out into a cream bottle; if more than this quantity is used, the fat column will be so large that it cannot be read in the bottle. The sample is then made up to approximately 18 grams by adding water. The purpose of adding water is the same as in testing cream: it retards the action of the acid. About 12 cubic centimeters of acid is then added; this quantity is sufficient because the solids-not-fat in butter are present in comparatively small proportions. The tests should be made in duplicate. From this point the test is conducted in the same manner as is the test for fat in cream. The fat column should be kept at the proper temperature, and glymol should be used in reading the completed test.

TESTING SOUR MILK

Sour milk should not be tested unless such testing is absolutely necessary. It is difficult to test sour milk because the casein has been precipitated and the fat is locked up in the particles of curd, making an even distribution of the fat impossible. The consistency of sour milk can be

made more like that of normal milk by the addition of strong alkali, which drives, or tends to drive, the casein into suspension. The particles of fat are then released. Caustic soda and caustic potash are useful in restoring the consistency of sour milk, and it is best to add them in the dry form because, when so used, they do not dilute the milk to any appreciable extent and it is unnecessary to make any correction when reading the fat column. If a liquid alkali is used, the milk is diluted and a corresponding correction must be made when the fat column is read.

TESTING CHURNED MILK

Churned milk should not be tested if it can be avoided. When it is absolutely necessary to test churned milk, the milk should be heated to about 85° F. and well shaken, and the sample should be drawn quickly. If the sample is badly churned, enough ether should be added to dissolve the fat. After thoroughly mixing, the sample is drawn, the ether is evaporated, and the quantity of ether taken is weighed. The sample is then tested in the usual manner, a correction in the reading being made for the quantity of ether used.

TESTING CREAM

In testing cream there are three main factors to be considered: first, taking the sample; second, getting the correct quantity of cream into the test bottle; and third, correct reading of the completed test.

Taking the sample

Before taking the sample the cream should be mixed by stirring. This must be done thoroughly and for about a half minute. If the cream is too thick it should be warmed until it pours readily, before drawing the sample. The quantity of cream used for the sample should not exceed 40 cubic centimeters, provided the sample is a representative one. Enough should be taken to make a duplicate test, and, since 9 grams is used in each test, 18 grams would be used in all. Therefore 40 cubic centimeters would be sufficient. Larger samples mean a waste of cream.

Weighing the cream

Before measuring the sample for the test, the temperature of the cream should be between 80° and 85° F. The sample should then be poured from one bottle to another and weighed at once. Heating it to a higher temperature is likely to melt the fat. If the fat is melted it is difficult to obtain a fair sample, since the melted fat quickly rises to the surface of the liquid.

The sample for the test should be taken by weight (Fig. 9), never by measure, for the following reasons:

1. The specific gravity of cream is so variable that the weight of the volume taken could not be relied upon.

2. Cream is so viscous that much of it would adhere to the inside of the pipette, and in this way lower results would be obtained.

3. Cream contains air bubbles and carbon dioxid (CO_2). These interfere in obtaining the correct volume. All cream bought on the fat basis in the State of New York should be weighed out for the fat test.

In Table 5 are shown the comparative results of weighing and of

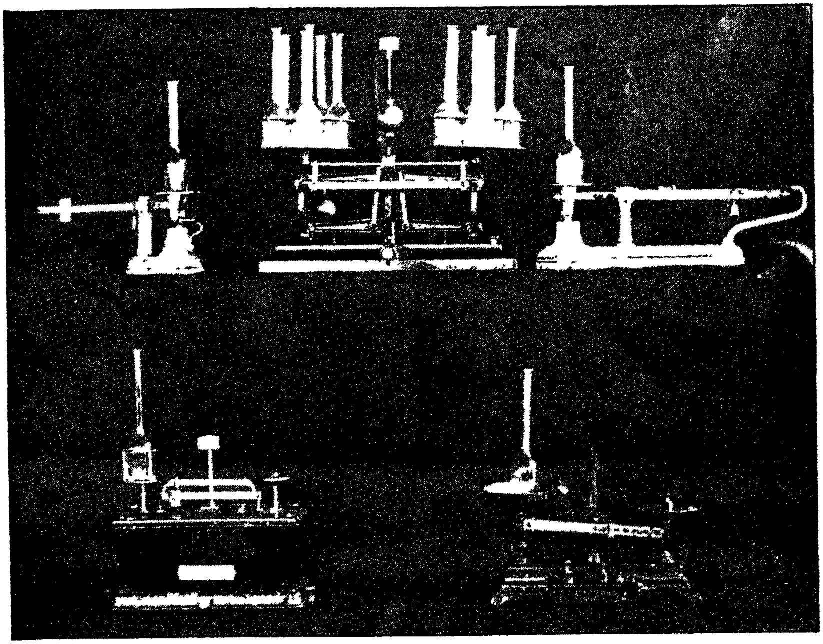

FIG. 9.— *Different styles of balances used in weighing cream for the Babcock test*

measuring samples of cream for the Babcock test. It will be noted that, the richer the cream, the greater is the difference between a weighed and a measured sample.

When the Babcock method was first used for testing cream, 18 grams or some fraction thereof was weighed into an 18-gram bottle. Oftentimes the percentage of fat was greater than was shown by the graduation on the bottle. For this reason only 9 grams was tested and the result was multiplied by two. The main objection to this method was that if a slight error were made in the test it would be twice as great in the final result, because the reading must be multiplied by two. The 9-gram

cream bottles (Fig. 10) are now coming into common use, and these do away with the calculation of results because they can be read directly in terms of percentage.

TABLE 5. COMPARATIVE RESULTS OBTAINED IN THE BABCOCK TEST BY WEIGHING AND MEASURING THE CREAM

Experiment	Percentage of fat		
	Cream weighed	Cream measured	Difference
1	41.5	40.0	1.5
2	44.5	41.0	3.5
3	44.0	39.5	4.5
4	31.0	29.0	2.0
5	45.5	41.0	4.5
6	33.0	31.0	2.0
7	33.5	31.5	2.0
8	35.0	33.0	2.0
9	31.0	29.0	2.0
10	23.5	22.0	1.5
11	24.5	22.0	2.5
12	32.5	31.0	1.5
13	32.0	30.5	1.5
14	32.5	30.5	2.0
15	43.0	41.0	2.0
16	31.5	30.0	1.5
17	30.0	28.0	2.0
18	27.0	26.5	0.5
19	24.5	24.0	0.5
20	21.5	20.0	1.5
21	19.0	18.0	1.0
22	26.0	25.5	0.5
23	19.0	18.5	0.5
24	9.5	8.5	1.0
25	11.5	11.0	0.5
26	13.5	13.0	0.5
27	21.0	19.5	1.5
28	33.5	31.0	2.5
29	21.5	20.0	1.5
30	37.0	35.0	2.0
31	33.5	31.0	2.5
32	32.0	30.5	1.5
33	31.5	31.0	0.5

When 9 grams of cream is used it might be expected that 9 grams of acid would be needed. It has been found by experiment that the best results can be obtained by weighing out 9 grams of cream and then making the weight approximately 18 grams by adding water. A little less than the usual quantity of acid is then added. After the bottles are placed in the machine the samples are tested in the same manner as is whole milk. When 9 grams of cream is used and 9 grams of acid is added to the cream,

a burned-fat column will often result. The addition of the 9 grams of water is made in order to retard the action of the acid, and in this way the burned-fat column may be avoided. The water used should be warm enough to rinse into the body of the bottle all the cream that adheres to the neck. If this cream is allowed to remain in the neck of the bottle it will be burned when the acid is added, and this will obscure the fat column. It will also result in a loss of fat, causing an error in the result.

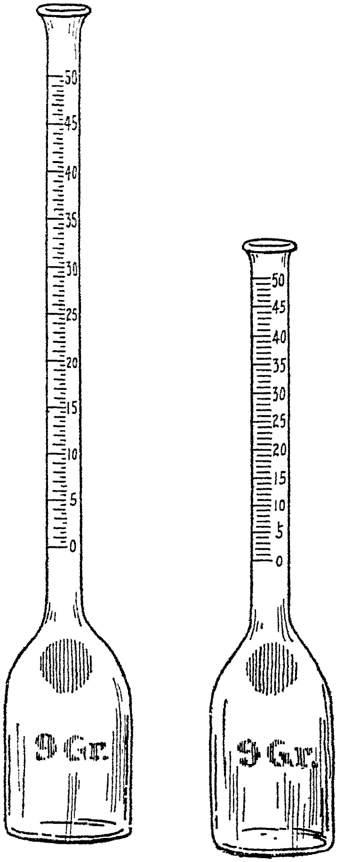

FIG. 10.— *Nine-gram cream bottles*

Reading the sample

Experience has shown that correct reading is the most difficult part of cream-testing. The two most important factors to be considered in reading the cream bottle are (1) the temperature of the fat column and (2) the meniscus.

Temperature of the fat column.— This should be between 140° and 150° F., as shown in Table 9. In order to have the fat column at this temperature it is necessary to immerse the bottles in a water bath (Fig. 11) at a temperature of about 150° F. for at least three minutes. This period is sufficiently long, as is shown by the results of the experiments in Table 6.

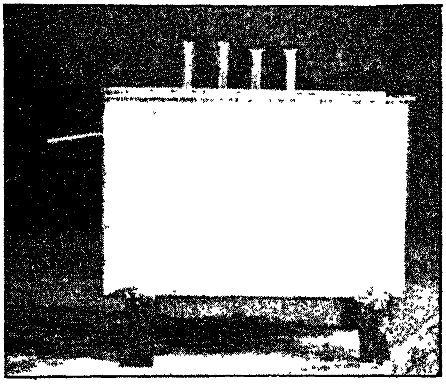

FIG. 11.— *Water bath*

The fact that the base of the bottle is warm is not an indication that the fat column is warm enough to be read. There should be enough water in the water bath to immerse the fat column. The temperature of the contents of the bottle varies in different parts; it is highest where the layers of water

and acid meet, and lowest in the fat column. Therefore it is necessary that the top of the fat column be below the surface of the water in the water bath.

TABLE 6. LENGTH OF TIME NECESSARY FOR FAT TO REACH SAME TEMPERATURE AS WATER IN BATH

Experiment	Temperature of water (degrees Fahrenheit)	Temperature of fat (degrees Fahrenheit)	Final temperature of both water and fat (degrees Fahrenheit)	Time immersed (minutes)
1	180	158	172	3
2	170	158	167	4
3	175	130	172	3
4	163	95	161	3
5	180	100	172	3
6	161	100	158	3
7	151	90	149	3
8	174	120	165	3
9	165	95	161	3
10	165	121	163	2½
11	161	100	161	2½
12	158	114	157	3
13	162	133	162	2½
14	158	106	158	2½
15	155	137	154	3
16	152	117	151	4
17	180	100	178	2
18	175	105	175	2
19	171	96	171	2½
20	166	89	165	2
21	133	115	132	2
22	132	115	130	2

The water bath can be constructed of any material, copper being preferable. Its top should be about one half inch lower than the cream bottles so that none of the water can enter the test bottles and interfere with the reading of the test.

The meniscus.— The other important factor to be considered is the meniscus. In the case of the whole-milk bottle the fat column is read from the extreme points of the menisci. The reason for this is in order to make up for the amount of residual fat in the base of the bottle. This cannot be done in the case of cream because the meniscus on the cream bottle varies from one to two per cent. This makes the percentage of fat expressed by the cream bottle unreliable. For a long time investigators have tried to obviate the error due to the meniscus, and finally the idea was conceived of adding something to the fat column in order to flatten it.*

*O. F. Hunziker. Testing cream for butter fat. Purdue Univ. Agr. Exp. Sta. Bul. 145.

After trying several substances, glymol, or white mineral oil, was found to best answer the purpose. Results of experiments with glymol are shown in Table 8. Glymol is a petroleum distillate, known commercially by the name "white mineral oil." It removes the meniscus and makes a sharp line of demarcation between the fat column and the added substance. The best results are obtained by adding it just before reading the test (Fig. 12), when the bottle is taken from the water bath. After the glymol is added it should be allowed to settle about a half minute before reading. About .5 cubic centimeter is sufficient.

TABLE 7. TEMPERATURE OF LIQUID IN DIFFERENT PARTS OF BABCOCK TEST BOTTLE

Experiment	Temperature (in degrees Fahrenheit)			
	Fat column	Base of neck	Center of bowl	Bottom of bottle
1	95	105	147	129
2	122	131	163	140
3	97	113	141	129
4	97	113	143	127
5	101	121	141	123
6	110	127	142	135
7	95	100	128	118
8	87	101	129	117
9	91	111	132	117
10	96	110	133	116
11	99	105	131	117
12	92	105	129	118
13	91	103	129	116
14	115	125	132	125
15	114	125	130	118
16	113	123	128	117
17	110	120	125	118
18	130	151	159	151

FIG. 12.— *Adding the glymol*

Experiments were tried by adding the glymol to the milk bottle before the addition of the acid. It was also added before the first addition of water directly after the first run. In another experiment it was added after the first addition of water and again after the second addition of water, but in each case the glymol united with the fat column and merely gave a larger reading.

The above experiments were tried on only four bottles. Two were 6-inch 9-gram bottles and the other two were 9-inch 9-gram bottles. In further experiments it was found that the meniscus varied with the bore of the bottle neck, the variations being from one to two per cent according to the style of bottle. The data show that the addition of glymol lowers the reading of the fat column in the short-neck bottles 1.5 per cent, and in the long-neck bottles the fat column is reduced but 1 per cent. Since the reading on the short-neck bottles is .5 per cent higher than the reading on the long-neck bottles, the same results are obtained in both cases.

TABLE 8. EFFECT OF USING GLYMOL IN READING THE FAT COLUMN IN A BABCOCK CREAM-TEST BOTTLE

Experiment	Percentage of fat shown					
	Before use of glymol		After use of glymol		In meniscus	
	Long neck	Short neck	Long neck	Short neck	Long neck	Short neck
1	23.5	24.0	22.5	22.5	1.0	1.5
2	43.5	44.0	42.5	42.5	1.0	1.5
3	31.5	32.0	30.5	30.5	1.0	1.5
4	33.0	33.5	32.0	32.0	1.0	1.5
5	30.5	31.0	29.5	29.5	1.0	1.5
6	32.5	33.0	31.5	31.5	1.0	1.5
7	33.0	33.5	32.0	32.0	1.0	1.5
8	33.5	34.0	32.5	32.5	1.0	1.5
9	43.0	43.5	42.0	42.0	1.0	1.5
10	44.0	44.5	43.0	43.0	1.0	1.5
11	45.0	45.5	44.0	44.0	1.0	1.5
12	28.5	29.0	27.5	27.5	1.0	1.5
13	29.0	29.5	28.0	28.0	1.0	1.5
14	38.0	38.5	37.0	37.0	1.0	1.5
15	39.5	40.0	38.5	38.5	1.0	1.5
16	41.0	41.5	40.0	40.0	1.0	1.5
17	42.5	43.0	41.5	41.5	1.0	1.5
18	39.5	40.0	38.5	38.5	1.0	1.5
19	39.5	40.0	38.5	38.5	1.0	1.5
20	39.5	40.0	38.5	38.5	1.0	1.5
21	27.0	27.5	26.0	26.0	1.0	1.5
22	16.0	16.5	15.0	15.0	1.0	1.5
23	19.0	19.5	18.0	18.0	1.0	1.5
24	11.0	11.5	10.0	10.0	1.0	1.5
25	46.0	46.5	45.0	45.0	1.0	1.5
26	44.5	45.0	43.5	43.5	1.0	1.5
27	43.5	44.0	42.5	42.5	1.0	1.5
28	35.5	36.0	34.5	34.5	1.0	1.5
29	47.5	48.0	46.5	46.5	1.0	1.5
30	48.0	48.5	47.0	47.0	1.0	1.5

Glymol gives a sharper line of demarcation if it is colored, and the coloring can best be done with alkanet root, an oil-soluble substance. The glymol, which, as stated above, is a white mineral oil, extracts the coloring principle from the alkanet root and assumes a bright cherry-red color. Alkanet, or Alkanna root, can be obtained at drug stores for about twenty-five cents per pound. One ounce of crushed alkanet root is used to one quart of glymol. A simple and convenient method of dissolving the alkanet root in the glymol is to wrap the alkanet root in a small piece of cheesecloth and place it in the vessel containing the glymol, leaving it in the glymol for one to two days.

Glymol may be used with or without the addition of coloring matter. It is best added by using a pipette or a burette and allowing the liquid to run down the inside of the neck of the bottle (Fig. 12). It is well to observe this precaution, for if the glymol is allowed to drop directly into the fat it will mix with the fat and give a ragged edge, and consequently make the reading difficult.

The chemical method compared with the Babcock method, ether being used as a fat extractor

The following table shows that, if the 9-gram bottle is used and the meniscus is removed by means of glymol, the Babcock method will compare very favorably for all practical purposes with the chemical method when read at a temperature between 140° and 150° F.

Sixty-four experiments were performed, both Babcock and chemical, and of that number there were thirty-five that compared within .2 per cent. The cream bottles are graduated only as fine as .5 per cent. Therefore it may be concluded that in this number of experiments there were only eight that varied more than .5 per cent.

Every experiment, both chemical and Babcock, was performed in duplicate. Only those that checked within .1 per cent were kept. The cream for the Babcock tests was always weighed on chemical balances. The fat column was tempered and the meniscus was removed in all cases.

TABLE 9. THE CHEMICAL METHOD COMPARED WITH THE BABCOCK METHOD. THE MENISCUS WAS REDUCED BY ADDING GLYMOL, OR MACHINE OIL, AND THE FAT COLUMN WAS READ AT 150° F.

Experiment	Percentage of fat shown		
	By chemical method	By Babcock method	Difference
43	21.35	22.00	+.65
44	22.44	22.00	−.44
45	22 47	22.50	+.03
46	37.68	38.00	+.32
47	28.12	28.00	−.12
48	28 56	28.50	−.06
49	44 91	45.00	+.09
50	34.80	35.00	+.20

TABLE 9 (*concluded*)

Experiment	Percentage of fat shown		
	By chemical method	By Babcock method	Difference
51	42.79	43.00	+.21
52	31.81	32.00	+.19
53	30.58	30.00	—.58
54	34.42	34.50	+.08
55	33.93	34.00	+.07
56	46.80	47.00	+.20
57	39.68	40.00	+.32
58	30.45	30.50	+.05
59	30.15	30.00	—.15
60	31.54	31.50	—.04
61	31.91	31.50	—.41
62	31.61	31.50	—.11
63	31.74	31.50	—.24
64	42.53	42.50	—.03
65	32.35	32.00	—.35
66	32.07	32.00	—.07
67	33.58	33.50	—.08
68	33.50	33.50	00
69	33.65	34.00	+.35
70	32.17	32.00	—.17
71	30.43	30.50	+.07
72	50.00	50.00	00
73	30.20	30.50	+.30
74	30.41	30.50	+.09
75	31.90	31.50	—.40
76	32.13	31.50	—.63
77	31.89	31.50	—.39
78	32.63	32.50	—.13
79	32.57	32.50	—.07
80	33.01	33.00	—.01
81	16.11	16.00	—.11
82	17.68	17.00	—.68
83	17.56	17.00	—.56
84	....	....	....
85	51.56	51.50	—.06
86	....	....	....
87	....	....	....
88	33.54	33.50	—.04
89	....	....	....
90	38.16	37.50	—.66
91	....	....	....
92	32.54	32.50	—.04
93	....	....	....
94	21.40	21.50	+.10
95	35.82	35.50	—.32
96	35.66	35.50	—.16
97	32.35	31.50	—.85
98	43.72	43.50	—.22
99	51.23	51.00	—.23
100	33.50	33.50	00
101	32.50	32.50	00
102	32.21	32.00	—.21
103	32.38	32.50	+.12
104	31.58	31.40	—.18
105	31.60	31.50	—.10
106	44.99	44.50	—.49

Recommendations

The following recommendations as to testing cream are offered as a result of this study:

1. After the sample of cream is taken, weigh out 9 grams into a 9-gram cream bottle The 6-inch 9-gram bottle is preferred; it is easily handled, can be used in any machine, and is accurate.

2. Add approximately 9 grams of water and a little less than the usual quantity of acid. This gives better results than adding half the regular quantity of acid directly to the 9 grams of cream.

3. Whirl for five minutes, add water to the base of the neck, whirl for two minutes, add enough water to bring fat into graduated part of neck, and whirl for one minute longer so as to bring all fat to the top.

4. Place in water bath (140° to 150° F.) and leave there for at least three minutes. Have the bath deep enough so that the water will surround the entire fat column.

5. After the sample has stood in the water bath for the required time, add the colored machine oil, or glymol. This is best done by using a burette and allowing the liquid to run down inside the neck of the bottle. This precaution had best be observed, for if the glymol is allowed to drop directly into the fat it will mix with the fat and give a ragged edge, and consequently cause difficulty in reading.

6. All tests should be made in duplicate.

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AN EXAMINATION OF SOME MORE PRODUCTIVE AND SOME LESS PRODUCTIVE SECTIONS OF A FIELD

BY T. LYTTLETON LYON, JAMES A. BIZZELL, AND H. JOEL CONN

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AN EXAMINATION OF SOME MORE PRODUCTIVE AND SOME LESS PRODUCTIVE SECTIONS OF A FIELD

(Received for publication September 18, 1913)

SOME PHYSICAL AND CHEMICAL EXAMINATIONS OF THE MORE PRODUCTIVE AND THE LESS PRODUCTIVE SECTIONS OF A FIELD

T. LYTTLETON LYON AND JAMES A. BIZZELL

In a field on the Cornell University farm used for experimental purposes, there were noticed, in 1905, two small tracts of land on which plant growth was poor. When first observed a crop of cabbage was growing on one of these tracts and the other was planted to timothy, the plants being about thirty inches apart each way. These areas were so unproductive, with so little apparent cause for their infertility, that an investigation of the matter was begun under the direction of Professor Thomas F. Hunt, who was at that time Agronomist of the Cornell University Agricultural Experiment Station. The initial experiments were conducted by F. R. Reid and J. F. Breazeale, of the Bureau of Soils, United States Department of Agriculture, and some mention of their work is made in Bulletin 36 (page 38) of that bureau. About the same time experiments with the soils were begun by C. F. Clark (1908)* as the subject of a thesis which he later presented in partial fulfillment of his work for the master's degree.

In the course of this experimental work the very interesting observation was made that, when soil from the unproductive areas was removed from the field and placed in pots, the first crop grown on it was better than that produced on soil from surrounding land which in the field was much more productive. This characteristic has remained constant up to the present time.

Clark afterwards removed blocks of soil from the fields with as little aëration as possible, this being accomplished by driving into the soil an iron cylinder about eight inches in diameter and eight inches long and transferring the soil taken in this cylinder to a wire basket, which was then sealed on the bottom and the sides with paraffin. When removed to the greenhouse without exposure of the interior of the core to air, the soil possessed the same relative productiveness that it did in the field.

*Figures in parenthesis refer to bibliography.

LOCATION AND COMPOSITION OF THE SOILS OF DIFFERENT QUALITIES

Location of the plats

In the spring of 1908 the larger and more strikingly unproductive area was divided into small plats $5\frac{1}{2}$ feet wide and 8 to 12 feet long This was done in order to ascertain how uniform in productiveness was the land; also, whether the poor areas yielded small crops every year, or whether, on the other hand, the small production were only a temporary condition. Since the difference between the two qualities of soil appeared to increase with lack of aëration, it was decided not to plow the land but to raise crops for a series of years, merely disking the soil in preparing the seed bed. During the years 1908 to 1911 the whole area, comprising 110 plats, was planted to the same crop, millet, and a record was kept of the yields on each plat. The yields for each year and the average yields for the four years are given in Table 1. These yields are calculated in grams of dry matter per linear inch of the drill. As each plat had the same number of drill rows, this gives a basis for comparing their productiveness.

As shown in the table, the yields on the various plats differ considerably. Some of the plats maintain low yields for each of the four years, while others maintain much better yields. Since the land was plowed in the spring of 1908 the yields are naturally much higher in that year; in addition it was a better season for the growth of millet than were the three succeeding years. As the result of these tests a number of plats were selected from among the high-yielding and a number from among the low-yielding plats, and on these were made mechanical soil analyses as well as determinations of volatile matter. Determinations of moisture and nitrates in field samples were also made at different times.

Correlation of the properties

This course of examination was followed in an attempt to correlate the low yields with some property of the soil that would account for its unproductiveness. It will be seen in Table 1 that there is no regular distribution of either the high-yielding or the low-yielding plats. There is a slight decline in elevation of the land from plat 1A, both toward plat 22A and toward plat 1E. The lowest point is plat 22E. The elevation is apparently not a determining factor in the quality of the soil.

Mechanical composition of soil

Mechanical analyses of the soil from a selected number of high- and low-yielding plats show that there is a gradual decrease in the clay and an increase in the sand as the slope of the land descends. In plates I and

II no correlation is shown between the productiveness and the mechanical composition of the soil, except at the extremes, where the highest-yielding plats have the highest clay content and the lowest-yielding plats have the lowest clay content.

Organic matter

Determinations of volatile matter were made in samples of the soils from the plats on which the mechanical analyses were made. The per-

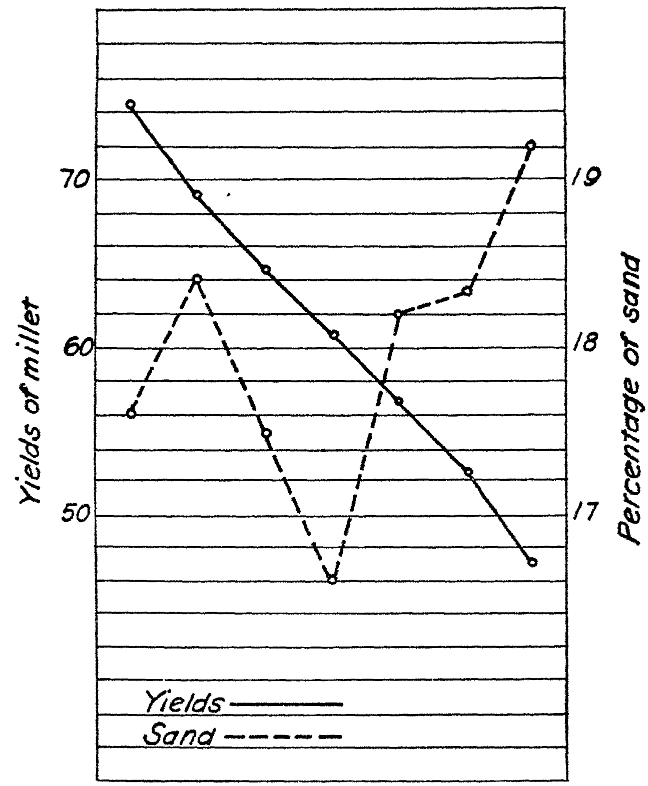


PLATE I.— *Average crop yields (in grams per linear inch) and percentage of sand in soil, calculated for seven groups of five plats each*

centage of substance volatile at dull redness should be a very good index of the content of organic matter in the soil of these plats, since the composition of the inorganic matter does not differ greatly.

The relation of the organic matter, as represented by the volatile material, to the crop yields is shown in Plate III. There is a fairly definite

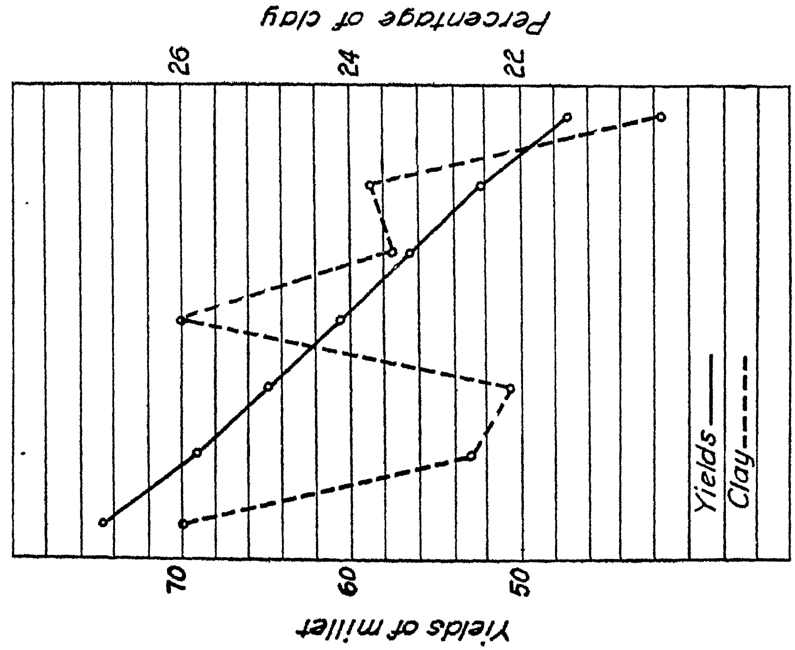


PLATE II.— *Average crop yields (in grams per linear inch) and percentage of clay in soil, calculated for seven groups of five plats each*

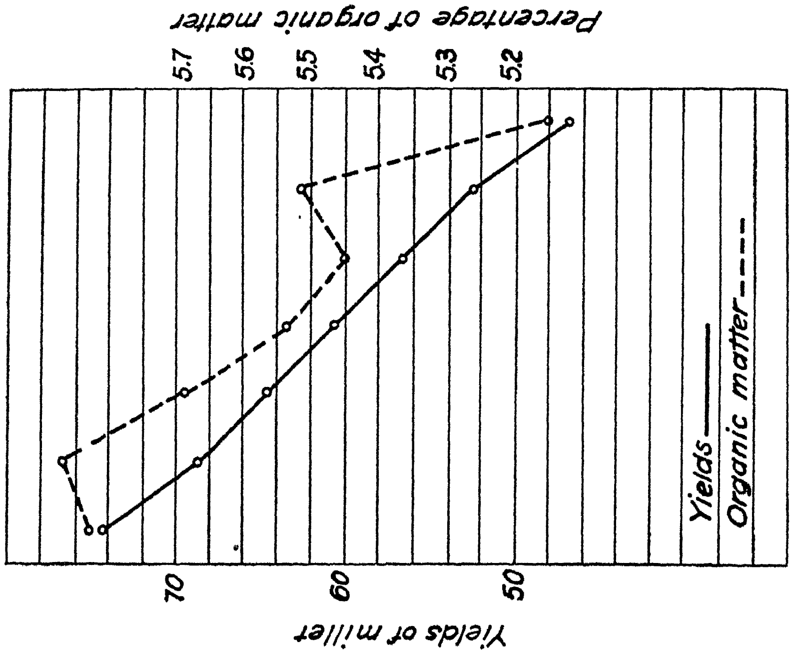


PLATE III.— *Average crop yields (in grams per linear inch) and percentage of organic matter in soil, calculated for seven groups of five plats each*

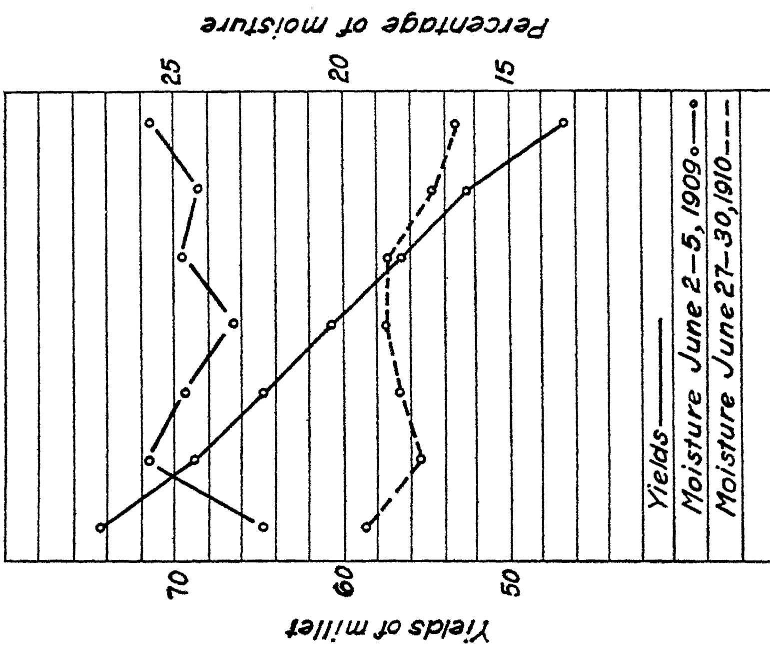


PLATE IV.— *Average crop yields (in grams per linear inch) and moisture content of soil, calculated for seven groups of five plats each*

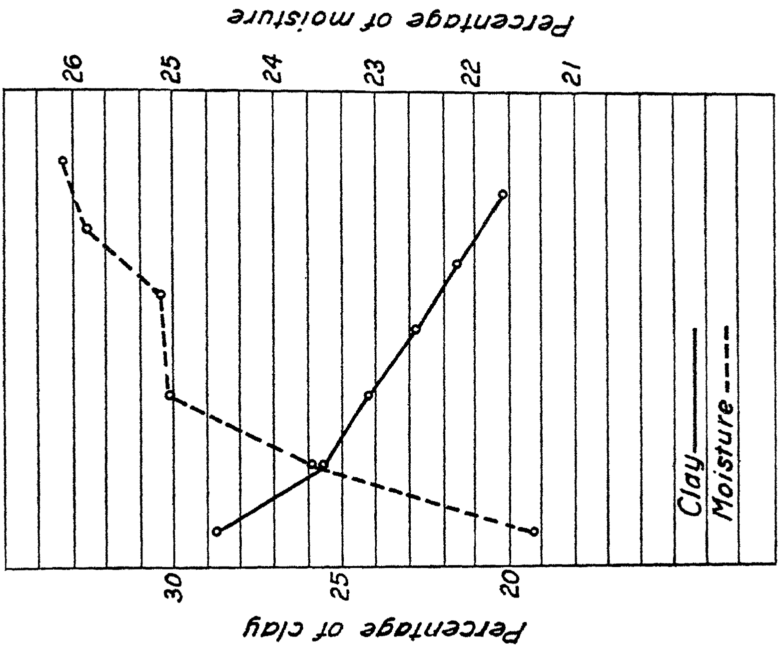


PLATE V.— *Percentage of clay in soil, and of moisture in soil June 2 to 5, 1909, averaged for six groups of five plats each*

relation brought out in this diagram. With a decrease in the productivity of the plats there is, in general, a decrease in the content of organic matter.

Moisture and nitrates

Moisture and nitrate determinations were made from samples of the soil on June 2 to 5, 1909, and on June 27 to 30, 1910, which was before the planting was done and yet after nitrification had well progressed. The nitrates at these periods should indicate the rate at which nitrate formation takes place on the plats in question. Three borings were made on each plat, a composite sample being formed from these. Both the first and the second foot were sampled, but only the results of analyses of the first foot are used since the second foot contained very little nitrate nitrogen. Another set of samples was taken in October, 1910, a few days after the crop was removed.

Moisture.— A tabulation of the yields and moisture contents of these plats fails to afford any reason to consider the moisture supply a very decisive factor in their productiveness. Moisture determinations were not made at a time when the soils were very dry, and therefore the capillary moisture capacity, which might have shown some relation to productiveness, is not evident. The moisture determinations shown in Plate IV were made in June, 1909, and in June, 1910, before the millet was planted. In 1910, when the moisture was fairly low, there was a decrease in moisture accompanying a decrease in yield on the poorer plats.

In Plate V the moisture in June, 1909, is shown to vary inversely with the content of clay. Since the moisture was very high at this time the relation is significant as showing the effect of clay on the saturation point of the soil. The lower moisture content of the following year failed to show any correlation with the clay.

Nitrates.—A very definite relation, however, is seen on an examination of plates VI and VII, in which the yields and nitrate contents of the soil are shown. The higher-yielding plats show a larger accumulation of nitrates before planting than do the very low-yielding plats. Evidently higher yields, on these plats, are associated with a more rapid formation of nitrates.

Chemical composition

In the autumn of 1907 samples of soil from the more productive and the less productive sections of the areas were taken for analysis. These samples were analyzed according to the method recommended by the Association of Official Agricultural Chemists. The results were as follows:

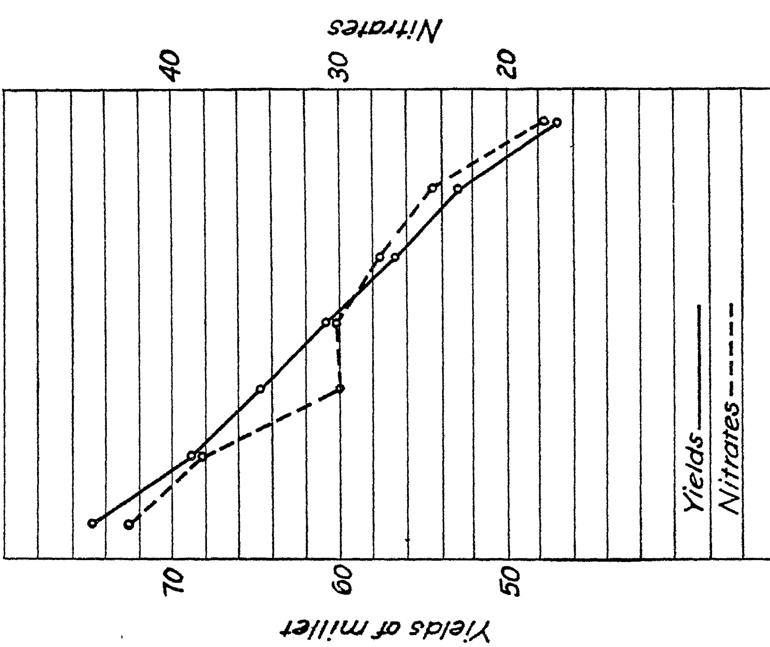


PLATE VI.—*Average crop yields (in grams per linear inch), and nitrate content (in parts per million of dry soil) June 2 to 5, 1909, calculated for seven groups of five plats each*

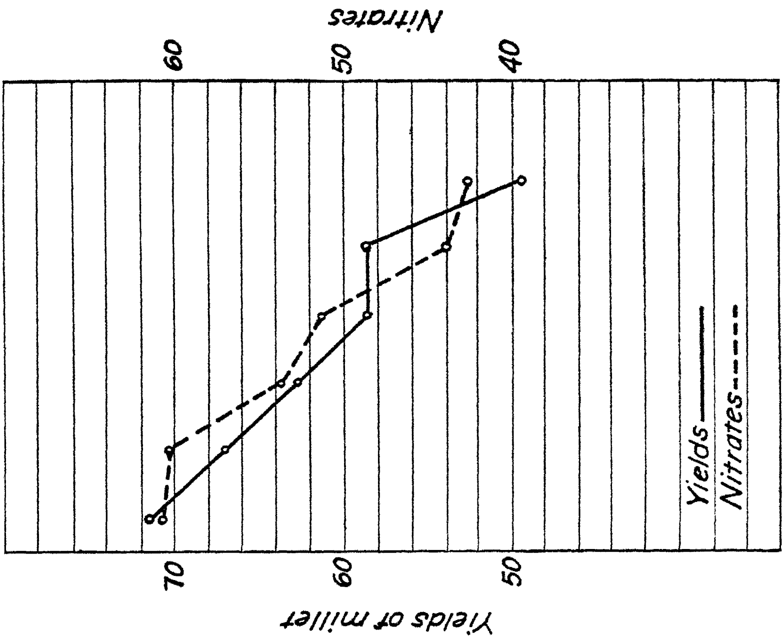


PLATE VII.—*Average crop yields (in grams per linear inch), and nitrate content (in parts per million of dry soil) June 27 to 30, 1910, calculated for six groups of five plats each*

	On the better soil (percentage)	On the poorer soil (percentage)
Moisture	1 700	1 470
Organic matter	6 770	5 560
Nitrogen	0 186	0.150
Phosphoric acid	0 207	0 175
Potash	0 480	0.430
Calcium oxid	0 380	0 230
Magnesium oxid	0 830	0 810

In taking these samples the borings for the better soil were all made at lower levels than those representing the poorer soil. For this reason there is, in these analyses, more difference between the better and the poorer soil in respect to composition than obtains in some of the later analyses, for which, in some cases, samples of the better soil were taken from higher levels than were the samples of the poorer soil.

Other samples taken a little later and representing a number of different locations on this area gave the following percentages of nitrogen:

	No. 1	No. 2	No. 3	No. 4
Better soil	0.154	0.214	0.201	0.171
Poorer soil	0.161	0.146	0.132	0.173

EFFECT OF AËRATION ON YIELD

Further examinations were made of the soil of some representative plats by growing plants on them in the greenhouse. It has already been remarked that the poorer soil, when taken from the field and well aërated, produced a larger crop than did the better soil. Experiments with greenhouse pots make it clear that this change is not a permanent one if the soil is allowed to remain in the pots without any more aëration than is required to plant the seeds of successive crops. In Table 2 are given the weights of a series of crops grown in soil from plats 1A, 4A, and 5A. Two crops were grown each year, of which one was wheat and the other was millet.

Yields of crops grown on soil taken from the same plats, but transferred from the field to eight-inch wire baskets with as little aëration as possible and grown at the same time and under the same conditions as the preceding, are shown in Table 3.

TABLE 2. YIELDS OF A SERIES OF CROPS IN POTS OF BETTER AND OF POORER SOIL NOT AËRATED AFTER PLANTING

	Yields of crops in grams			
	Dry matter		Nitrogen	
	Better soil (pots 15, 16)	Poorer soil (pots 17, 18)	Better soil (pots 15, 16)	Poorer soil (pots 17, 18)
First crop after potting	19.7	25.3	0.1726	0.2160
Average of five succeeding crops	13.4	11.5	0.1238	0.1104

TABLE 3. YIELDS OF A SERIES OF CROPS IN BASKETS OF BETTER AND OF POORER SOIL NOT AËRATED INTENTIONALLY WHEN BROUGHT FROM FIELD

	Yields of crops in grams			
	Dry matter		Nitrogen	
	Better soil (baskets 41, 42)	Poorer soil (baskets 43, 44)	Better soil (baskets 41, 42)	Poorer soil (baskets 43, 44)
First crop after potting	21.2	20.6	0.2129	0.1910
Average of five succeeding crops	15.4	11.7	0.1455*	0.0928*

* Average of only four crops.

EFFECT OF AËRATION ON FORMATION OF NITRATES

One effect of aeration on the soil from these plats was made evident when samples of the aërated and of the unaërated soil were analyzed for nitrates. For the purpose soil was taken from plats 1B, 4B, and 5B, both in an unaërated condition by means of an iron cylinder, as has already been described, and by digging up the soil, thus allowing it to aërate but not to dry, and transferring it to a receptacle similar to that in which the unaërated soil was placed. This was done on October 15, 1908. The soil stood in the greenhouse without being planted but being maintained at a moisture content of 25 per cent of the weight of the soil. Nitrates were determined on November 7, 1908, and on January 5, 1909. The results are given in Table 4:

TABLE 4. NITRATES IN AËRATED AND IN UNAËRATED SOIL OF BETTER AND OF POORER PLATS WHEN ALLOWED TO STAND UNDER SIMILAR CONDITIONS

Plat	Soil	Nitrates (parts per million in dry soil)	
		November 7, 1908	January 5, 1909
4B and 5B.	Better soil, unaërated. . ..	4 2	9 7
4B and 5B..	Better soil, aerated	17.6	26 0
1B.... ..	Poorer soil, unaerated. .	4 2	Trace
1B .. .	Poorer soil, aerated .	15 4	28 9

The beneficial effect of aeration on nitrate formation is very evident in both soils, but more so in the poorer soil than in the better. The analyses of January 5, 1909, indicate that lack of aëration must be a very important factor in causing the soil of plat 1B to yield smaller crops than those of 4B and 5B, since only a trace of nitrates was found in the unaerated soil from plat 1B as compared with 9.7 parts per million in the unaërated soil from plats 4B and 5B, while the nitrates are slightly higher in the aerated soil from 1B than in the corresponding soil from 4B and 5B.

VOLUME WEIGHT OF SOILS

Determinations of the volume weight and the volume of interstitial space were made in plats 1A, 1B, 4A, and 4B in the following manner: An iron cylinder eight inches in diameter and eight inches long was driven into the soil. The column of soil, with the cylinder, was removed by digging the soil from around it and detaching the column from the lower soil by inserting a spade under the cylinder. The top and the bottom of the soil column were then trimmed flush with the ends of the cylinder. The weight of the column of soil was thus obtained, and the percentage of moisture was determined in order to obtain the weight of dry soil. The interstitial space was calculated from these data.

The average pore space for plats 1A and 1B, representing the poorer soil, was 37.5 per cent; that of 4A and 4B, representing the better soil, was 42.1 per cent. In this case the volume of interstitial space was in the same order as the moisture content, which was 22.3 per cent for plats 1A and 1B and 22.8 per cent for plats 4A and 4B. The sample was taken on November 14, when there was an abundant supply of moisture in the soil.

Another determination of the volume of interstitial space, in samples taken from sections of the area before the small plats were laid out, was made by J. H. Squires. He found the pore space to be 51.2 per cent in the better soil and 50.2 per cent in the poorer soil. The moisture content was 11.8 per cent and 10.7 per cent, respectively.

GROWTH OF SEEDLINGS IN WATER EXTRACTS

A very extensive series of tests with soil from some of these plats was conducted by J. H. Squires (1909). Among other things he grew wheat seedlings in the aqueous extracts of the soils. He desired to ascertain whether the extract of the better soil produced a better growth than did that of the poorer soil, and, if so, why this was the case.

An analysis of the extracts of the soil used gave, when calculated to dry soil, the following:

	Parts per million dry soil		
	Nitrates (NO_3)	Phosphates (PO_4)	Potassium (K)
Better soil	36 4	11.0	9.7
Poorer soil	32 5	11.7	9.1

This analysis shows very little difference in the quantities of nutrients in the extracts, probably not sufficient to produce any difference in the yields of seedlings grown in them.

Nine separate tests were made, extracts of soil from the better and the poorer plats being used in each test. In each test four bottles were used with each of the extracts and four plants were grown in each bottle, making a total of one hundred and forty-four plants grown in each of the extracts. Wheat was grown for about four weeks in the extracts, the seed having been germinated before being placed in the bottles. The yields of dry matter for each test are given in Table 5:

TABLE 5. YIELDS OF DRY MATTER IN WHEAT GROWN IN EXTRACTS OF SOIL FROM BETTER- AND FROM POORER-YIELDING PLATS (IN MILLIGRAMS)

Test	Soil of better plats	Soil of poorer plats
1	80 0	90.0
2	103.4	90.7
3	85.3	58.9
4	153 4	94 6
5	179.2	133.6
6	66 8	62.4
7	66.4	89.4
8	98.5	86.7
9	84.1	101.2
Average	101 9	89.7

The majority of the tests were in favor of the extracts from the better soil, but three of the nine tests resulted in better yields from the extracts

from the poorer soil. This is not very conclusive evidence in favor of the extracts from the better plats.

At the same time when these cultures were grown similar tests were made with other portions of the extracts, which were shaken with well-washed carbon-black, filtered through filter paper, and used as cultures for wheat seedlings. The results are stated in Table 6:

TABLE 6. YIELDS OF DRY MATTER IN WHEAT GROWN IN SOIL EXTRACTS TREATED WITH CARBON-BLACK (IN MILLIGRAMS)

Test	Soil of better plats	Soil of poorer plats
1	70 0	100.0
2	92.7	103.3
3	89 2	76.2
4	192.6	118.7
5	133.7	89.8
6	65.6	86 0
7	76 2	68 3
8	79.9	81.7
9	89.0	106.9
Average	98 8	92.3

In five of these tests the larger yields were produced by the extracts from the poorer plats, although the average was slightly greater for the better ones. The effect of the treatment with carbon-black was so slight that it cannot be regarded as removing any toxic substance from the soil extract and thus making it a better medium for the growth of wheat seedlings. If the poorer growth of wheat seedlings in the extract of the poorer soil was due to a toxic substance or substances, there has been no demonstration of it. On the other hand, the analyses of the soil extracts from the better and the poorer plats show very little difference in nutrient salts.

RECAPITULATION

A recapitulation of the various examinations that have been made of the soil of the representative plats will permit of an analysis of the conditions. When the whole area was divided into small plats $5\frac{1}{2}$ feet wide and 8 to 12 feet long and these plats were cropped with millet for four years, there was a fairly constant relation in the yields of the various plats. The more productive plats maintained this characteristic, as did also the less productive ones, from which it may be inferred that the relative yields were not accidental but were governed by conditions that remained fairly constant.

The more productive and the less productive plats were not distributed with any definite relation to the topography of the area, although several plats of somewhat similar productiveness were sometimes contiguous.

Mechanical analyses of the soils showed that the texture underwent a gradual change from the upper to the lower part of the area. There was no constant relation between the productiveness of the plats and their mechanical composition, although, as will be shown later, the texture proved in some cases to be a factor in determining productiveness. Chemical analysis showed no great difference in the inorganic constituents.

The moisture content of the soils lay in no relation to the yields. A very definite relation was found to exist between the rate of nitrate formation in the soils and their productivity. Likewise the quantity of organic matter and the yielding qualities of the soils were generally, but not always, correlated.

Both observation and a number of tests brought out the fact that the lower-yielding plats were more compact than the higher-yielding ones. The degree of compactness was evidently due, in large measure, to the quantity of organic matter, and in less degree to the soil texture. An examination of plates I, II, and III shows that when the organic matter fails to decrease with a decrease in yield, as is the case between groups 5 and 6 in Plate III, there is an increase in the percentage of clay and only a slight increase in the percentage of sand. The degree of compactness may be considered to determine the crop yield, and the organic matter and the texture determine the degree of compactness. This rule fails only in the case of group 1, which is composed of five of the highest-yielding plats.

The results of the determinations of nitrates in both years are in accord with this conclusion, since these determinations show that the nitrates decrease with the yields. The more compact condition of the soil was naturally less favorable to the formation of nitrates, and thus the qualities of productiveness, compactness, and rate of formation of nitrates are correlated. The presence of large quantities of nitrates is not the most important factor concerned in the production of millet on this soil, but the less compact condition with which their ready formation is associated permits of the contributing to plant growth of the other processes in the soil.

Considering again the effect of aëration, which was to increase temporarily the productiveness of the poorer soil beyond that of the better and to increase greatly the formation of nitrates, further evidence is obtained that a compact condition of the soils is the factor that interferes with the processes necessary to liberate the plant-food.

It may therefore be concluded that a too compact condition of the soil is the cause of the lessened productiveness of certain small sections of this soil for the growth of certain crops.

STUDY OF BACTERIAL FLORA

One of the lines of investigation undertaken in connection with the examination of these plats was a study of the bacterial flora, conducted by H. J. Conn. Since this brings to light some new and very interesting aspects of soil bacteriology, it is printed herewith in full.

Soils used for bacteriological study

The plats selected for Conn's work were 1B and 4B. Their respective yields of millet for the years 1908 to 1911 were as follows:

TABLE 7. YIELD OF MILLET (IN GRAMS PER LINEAR INCH)

Plat	1908	1909	1910	1911	Average
1B	70 4	11.7	56 7	84 1	55.7
4B	122 8	32.8	83 9	98 7	84 6

Soil taken from these plats and transferred to wire baskets without aèrating, in the manner already described, yielded the following succession of crops of wheat and millet when kept for a number of years in the greenhouse:

TABLE 8. YIELDS ON SOIL FROM PLATS WHEN KEPT IN GREENHOUSE

Year	Kind of crop	Weight of dry matter in crop (in grams)	
		Plat 1B	Plat 4B
1908–1909	Wheat	20.60	21.21
1909	Millet	13.64	21.97
1909–1910	Wheat	15.10	20.21
1910	Millet	14.27	20 26
1910–1911	Wheat	10.04	7.99
1911	Millet	5.41	6.41
Average		13.18	16.34

In Table 9 are given the determinations of a number of other properties of the soils in plats 1B and 4B:

TABLE 9. DETERMINATIONS OF A NUMBER OF PROPERTIES OF THE SOILS FROM PLATS 1B AND 4B. (ALL CALCULATIONS MADE TO WATER-FREE SOIL)

Plat	Interstitial space (percentage)	Sand (percentage)	Silt (percentage)	Clay (percentage)	Volatile matter (percentage)	Moisture (percentage)			Nitrates (parts per million)			Total nitrogen (percentage)
						June 2, 1909	June 27, 1910	October 10, 1910	June 2, 1909	June 27, 1910	October 10, 1910	
1B	37.1	12.1	49.5	37.5	5.22	19.0	19.7	22.6	9.8	7.4	8.8	0.173
4B	38.0	16.0	56.7	27.8	4.99	21.2	18.9	30.3	29.5	59.1	10.2	0.171

Since plats 1B and 4B are fairly representative of the less productive and the more productive soils on this area, the observations of the bacterial flora are accompanied by a fair knowledge of a number of the other properties of the soils. The bacteriological study enters an unexplored territory, and, although it contributes nothing to the knowledge already existing as to why soils are more or less productive, the other examinations furnish a very good vantage ground from which to observe the data obtained from the bacteriological study.

A CLASSIFICATION OF THE BACTERIA IN TWO SOIL PLATS OF UNEQUAL PRODUCTIVITY

H. JOEL CONN

A study is herewith presented of the bacteria found in two neighboring soil plats of unequal productivity. It is of interest for two reasons: (1) since it is one of the early attempts to classify the general bacterial flora of soil, it furnishes some rather interesting information as to the normal soil bacteria; and (2) it gives an opportunity to observe whether in this particular case there is any correlation between the productivity of soil and its bacteria content. The results are somewhat indefinite, it is true, but possibly they may be a preliminary step toward a better knowledge of soil organisms.

This work is qualitative as well as quantitative. In spite of the difficulties inherent in bacteriological work, which make it necessary to keep the investigation within narrow limits, it has not seemed wise to confine it to a mere enumeration of the bacteria. For quantitative work alone the samples could have been taken oftener but the data would probably have been of less value. The bacteria, therefore, not only have been counted, but also have been classified as well as present rudimentary methods allow.

REVIEW OF LITERATURE

Existing knowledge of the soil bacterial flora is very meager. Most of this knowledge either is quantitative or else relates to certain special groups of organisms.

Quantitative work

Quantitative work has been common. Usually, however, it has been on soil kept in the laboratory or the greenhouse, and can hardly be compared with the present study of field soil; or else, if field soil has been used, the samples have been taken at long intervals or for but short periods. A few investigations on the numbers of soil bacteria are important enough to be worth mentioning.

The earliest application of the plate method to soil was by Fränkel (1887). Caron (1895) made a more extensive study of soil bacteria by the same method. About five years later Chester (1903) did still more work of this nature. Remy (1902) seems to have been about the first to make a continued study of the quantitative variations among the bacteria of field soil throughout any considerable period of time; but, since his attention was directed primarily toward the behavior of the mixed flora when inoculated into various media, his quantitative data are treated as a mere side issue. Hiltner and Störmer (1903) published some very extensive data showing quantitative variations in field soil, and conducted their work in such a systematic manner that it is of great value. Fabricius and Von Feilitzen (1905) published some data of the same nature which are also valuable. Krüger and Heinze (1907), in the course of some experiments on fallowed land, have furnished data in regard to seasonal variation in numbers of soil bacteria. Lipman and Brown (1908) have published data of the same nature; but their attention, like Remy's, has been turned to the chemical means of investigation, with the result that their quantitative methods have not been perfected. Fischer (1909, a and b) has published some quantitative data which furnish a comparison between various soils. Engberding (1909) has published some extensive data on seasonal variation, which he correlated with weather conditions.

There is but little agreement among the results of this quantitative work. Numbers vary, roughly speaking, from one hundred thousand to one hundred million bacteria per gram of soil; but in the same soil the numbers are moderately constant. They vary considerably between different soils, and in general the more productive soils contain the greater numbers of bacteria; but to this there are striking exceptions. Some writers find the numbers in a given soil varying with soil moisture, others with temperature.

Qualitative work

Qualitative work is still more indefinite. It has been confined almost wholly to the bacteria concerned in the transformations of nitrogen. These interesting and important organisms have been so frequently studied in the past that it has seemed wise — in spite of all that still remains to be learned concerning them — to omit them from the present

investigation. For this reason no review of the extensive literature on the subject is attempted

It is well known that vast numbers of soil bacteria have never been shown to have anything to do with nitrogen transformations. Yet so great has been the interest in the nitrogen bacteria that no one has ever made a thorough qualitative investigation of the general soil flora. Hiltner and Stormer (1903) made a preliminary step in this direction by classifying the colonies developing on their gelatin plates into liquefiers, non-liquefiers, and Streptothrix. These three groups are still recognized, but seldom has any one attempted a systematic study of them in pure culture. Gottheil (1901) and Neide (1904), it is true, made a careful study of those gelatin liquefiers known as the *Bacillus subtilis* group — a group that is concerned also in the ammonification of nitrogen; and Chester (1904) proposed a method for the systematic study of the predominating bacteria in any soil. But the work of these investigators is only a beginning, and most of the field is wholly unexplored.

In the course of this work it has often been suggested that lack of the proper bacteria might be the cause of low productivity in some soils. It was early claimed that the productivity of different soils was proportional to the numbers of bacteria that they contained. When this was found to be untrue it was hoped that certain kinds of organisms might be discovered whose presence assured fertility. Caron (1895), in the work already mentioned, observed apparent benefit from the inoculation of poor soils with various bacteria isolated from good soils; but the organism which he particularly recommended proved, after some commercial exploitation, to be of little, if any, use. This, together with other similar work, has led to the opinion that the explanation of the unproductiveness of soils is less likely to be the absence of any particular organism than the existence of conditions unfavorable to beneficial bacteria. Ehrenberg (1904), for example, made a study of a soil that was "bacteriologically abnormal," and found it to become normal when treated with lime. Very similar were the conclusions of Wohltmann, Fischer, and Schneider (1904).

In the meantime the question has been raised as to whether certain soils might not contain organisms directly harmful to plant growth. Koch (1899) suggested that grape fatigue might be due to a bacteriological factor. In order to determine whether this is true he treated good soil with an extract of the exhausted soil and observed the effect to be harmful if the extract was not sterilized. Recently Dachnowski (1909) took up the subject from a different point of view, isolating certain cultures from a very toxic bog soil and observing the effects of these cultures on wheat seedlings grown in a sterilized extract of the soil. He claims to have found a retardation of his plants due to the direct action of these bacteria.

Still more recently Russell and Hutchinson (1909 and 1913) have made a study of various unproductive soils and have concluded that the fault is due to some organisms harmful to bacteria.

Other methods

A still different way of determining the relation between bacteria and productivity is to make a systematic study of the flora of two soils similar in structure, texture, and chemical composition but different in crop-producing power. The present work is an attempt to do this. As yet no one seems to have made such a study, but various methods have been described for making a bacteriological comparison between two or more soils. Such literature is worth reviewing.

In most cases these previous methods have used, as a basis of comparison, the organisms concerned in nitrogen transformations. The best-known method of soil investigation is the Remy method, a procedure recommended by Remy, by Löhnis, and by Lipman for studying the mixed flora of soil.* Briefly, this procedure consists in the inoculation of various liquid media with a definite weight of soil, and the determination of the amount of chemical change that has taken place at the end of a definite length of time, using media adapted respectively for the nitrifiers, ammonifiers, denitrifiers, and nitrogen-fixers. The extent to which these various activities take place in the solutions, when inoculated with different soils, serves as a basis of comparison for measuring the bacterial activities of the respective soils.

This method is based on the assumption that the processes taking place in these liquid media are proportional to the changes produced by the organisms of the soils if left under their natural conditions. Fischer (1909, c, d, and e) has recently objected to this assumption. Still more vigorous objections have come from Stevens and Withers (1909, a and b), who have proposed a modification of the method in which soils instead of solutions are used for the tests. The present writer has elsewhere (1910 a) criticized the method on another score, which applies to Stevens and Withers' modification as well as to Remy's method itself. This criticism is that by this method an unknown number of unknown organisms are placed under uncontrollable conditions, and the results alone are studied without attention being paid to the processes themselves.

Other writers have proposed still different means for making a bacteriological comparison of soils. Among such writers are Hiltner and Störmer (1903), who suggested, first, a determination of the relative numbers of liquefying, non-liquefying, and Streptothrix colonies on the plates, and, secondly, an enumeration of the ammonifiers, nitrifiers, and denitrifiers by means of

*For a description of this method see reference in bibliography to Remy (1902).

a dilution method. The first of these suggestions has been adopted in the present work. Chester (1904) proposed what he called a "quanti-qualitative analysis" of the soil. From his plates he estimated the relative numbers of the predominating types of bacteria, and then determined the ability of these types to produce acid and ammonia when grown in pure culture. Many of his methods have proved especially suggestive.

Meanwhile, in dairy bacteriology certain methods have been developed for comparing the general flora of different samples of milk or cheese, which have never yet been extensively used in soil work. Conn and Esten (1903 and 1907) were the first to make a systematic study of milk bacteria, and their classification has led the way to considerable study of the bacterial flora of milk. More recently Harding and Prucha (1908) have employed some of the most advanced qualitative methods in their study of the bacterial flora of cheddar cheese. By these methods a qualitative comparison can be made of the bacterial flora as influenced by varying conditions. The present investigation is an attempt to apply the same methods to soil.

METHODS OF THE INVESTIGATION

In order to accomplish the purpose desired, some system is necessary by which qualitative data can be obtained that are sufficiently accurate yet not too voluminous to be easily handled. The system must also be such as to furnish information that later workers may be able to use. Only two systems of bacteriological classification give any information that is as accurate as is desired — the system of Meyer (1903) and that of the Society of American Bacteriologists.*

The system of Meyer and his school bases the classification of bacteria primarily on morphology, that of the Society of American Bacteriologists chiefly on physiology. The former system is claimed by its exponents to distinguish separate species of bacteria with extreme accuracy; but it is applicable only to large, spore-bearing bacteria, and requires a very skillful microscopical technique. The latter system is not regarded, even by those who employ it, as a method for the accurate recognition of species; but it is applicable to all bacteria that grow in ordinary media, and does not require such a highly perfected technique. Since the physiological types established by the American system are possibly of greater practical importance and are certainly much more easily distinguished one from another than the botanical species of Meyer's system, it has seemed well to adopt for the present work a modification of the methods of the Society of American Bacteriologists.

* For a description of this method, see reference in bibliography to Harding (1910).

Briefly, the methods employed have consisted of making plates directly from field soil, studying the colonies that have appeared, and enumerating each sort of colony; then isolating representatives of each sort and studying them by means of microscopical, cultural, and biochemical tests; and lastly arranging the cultures studied into species or types, and studying the complete characteristics of the various types.

Such a study as this, of course, by no means reaches all the organisms living in the soil. Higher fungi and protozoa are omitted. Large numbers of bacteria, such as obligate anaerobes and those incapable of growing on the ordinary highly organic and poorly aërated media, are undoubtedly excluded; many of these, such as the nitrifiers, are of great significance in the soil. It is quite possible, indeed, that the methods employed in this work neglect by far the greater number of soil bacteria. The other organisms have not been included in this study merely because of the necessity of limiting the work to an amount small enough to be easily handled.

Sampling soil

Samples of the soils were usually taken by means of an auger, or by the combined use of auger and pick when the soil was frozen. During the winter of 1909–1910, however, a pick alone was used. When an auger was employed the proceeds from two or three borings were combined — except in winter, when only one hole was made; but when the pick alone was used it was impossible to take any such pains in order to obtain a representative sample. It must therefore be remembered that in January and February, 1909, the soil was not quite so well sampled as ordinarily. (The same thing is true of the September sample in 1909, when it chanced that no auger was available.) The depth of sampling was six to eight inches, although in the winter of 1909–1910 the depth varied more than during the remainder of the period. The tools used were always cleaned; it seemed unnecessary, however, to use absolutely sterile tools, because, in view of the high dilutions used, any contaminations thus introduced would appear on the plates only as isolated colonies, and in this study no attention has been paid to any forms not present on the plates in more than two or three separate colonies.

Mixing soil, and diluting

Immediately after reaching the laboratory the soil was carefully mixed, in summer by sifting through a sieve as fine as the moisture content would allow, in winter by stirring after thawing. Of this soil, .5 gram was added to sufficient sterile water to make a volume of 100 cubic centimeters.

The flask containing this mixture was shaken vigorously for two minutes; then, giving the contents of the flask a whirling motion, 1 cubic centimeter of the suspension was removed with a sterile pipette before the motion of the liquid ceased. This 1 cubic centimeter was again diluted with sterile water so as to make a volume of 100 cubic centimeters, making a strength such that each cubic centimeter represented 1/20,000 gram of soil. Further portions of this suspension were removed, using the same whirling motion, and were diluted respectively five and ten times so as to obtain dilutions of 1/100,000 and 1/200,000. On special occasions a further dilution of 1/500,000 was used.

During this process of mixing and diluting, care to avoid air infection was taken only after selecting the .5-gram sample from the larger mass of soil — although as a rule the soil was never left uncovered in the laboratory for more than a few seconds at a time. Even after the selection of this small sample it was not entirely protected from such infection until mixed with water. Care to prevent this contamination seemed as unnecessary — and for the same reason — as the use of sterile tools in taking the samples.

Another portion of the soil was in all cases weighed out and dried in order to determine the moisture content, so that all computations of numbers of bacteria might be referred to a dry basis.

Plating

One cubic centimeter of the proper dilution was finally placed in a sterile petri dish and 10 cubic centimeters of the melted gelatin or agar was poured on it, the plate being tilted carefully back and forth until the contents were thoroughly mixed. At least three plates of each dilution were always made.

The medium used most extensively throughout this work was a gelatin containing nothing but soil extract and .1 per cent of dextrose (Table 18, page 111). In the early work this medium contained ammonium tartrate as well, but this was soon found unnecessary and was omitted. The first two samples from each plat were plated in a different gelatin, recommended by Hoffmann (1906), which contained not only soil extract but also beef extract and peptone. This medium was found to give lower counts than did the gelatin used in the later work, and allowance for this fact must be made in interpreting the results from these first two platings. Certain agar media, such as those recommended by Fischer (1910) and by Lipman and Brown (1908), were used at times for comparison with this gelatin; although giving higher counts on some occasions, these media were not extensively used because the colonies developing on them all looked too nearly alike for the classification necessary in qualitative work.

Incubation

A temperature of 19° to 20° C. was employed for incubation, ice being used in summer in order to keep the temperature sufficiently low. The period of incubation was seven days for all gelatin plates, but usually two weeks for agar.

Quantitative study

After incubation the colonies on the plates were counted and the number of bacteria per gram of dry soil was estimated, the results obtained from each of the parallel plates being averaged. In making this estimate the results from the dilution 1/20,000 have generally been disregarded, as the bacteria on these plates were usually so crowded that all could not produce colonies. The estimate was based on the dilution 1/200,000 usually, but on the dilution 1/100,000 when the numbers of bacteria were small.

Qualitative study

Classification and isolation of colonies.—At the end of seven days the gelatin plates were carefully studied and the colonies were classified into as many sorts as seemed distinct. Of each sort three or more representatives were usually isolated and kept for future study. The numbers of each sort were determined and an estimate was made of the approximate numbers per gram of soil represented by each.

Great pains were taken in this particular part of the work, for on the care employed in the classification of colonies depends the accuracy of the study of the cultures. An examination of the colonies was always made, using both the naked eye and the low power of a microscope, in order to recognize as many as possible of the different organisms by their colonies. Even with this great care, however, it is usually impossible to distinguish between many of the common types, since it often happens that more than one type of organisms will produce colonies exactly alike in appearance or that the same type may occur in two or more different forms. This study of the plates, therefore, is not always so satisfactory as might be desired.

Study of pure cultures.— The cultures isolated from the original plates (often amounting to thirty to forty from each soil sample) were studied as fast as time would allow. Within a few days of their isolation a process known technically as purification was performed on each culture. This process consists of plating the culture in agar or gelatin and, when the plates have matured, isolating a culture from a colony like the original, thus assuring its freedom from any contamination that might have been taken from the original plate together with the desired organism. After purification the cultures were kept until it was convenient to study them.

Before actual study, however, a process known as invigoration was performed. The purpose of invigoration is to bring back to their natural vigor organisms that have become attenuated by adverse conditions. The procedure adopted as standard by the American Public Health Association (1912) is to inoculate the organisms into three successive daily transfers of broth at 37° C. Many soil bacteria, however, will not grow at all in broth and must be invigorated by some other method or else left uninvigorated. To dispense with invigoration is not a good practice when cultures must be held in the laboratory for varying lengths of time before study; therefore it was finally decided to use an arbitrary procedure when the standard method failed.

The method of invigoration finally used was to incubate each culture in broth at 30° C. (if it develops at that temperature) until a good growth appeared, and then to allow it to grow for the same length of time in the next two transfers of broth. In case of failure to grow under these conditions a lower temperature was first tried, and then other media were employed. The few cases when this change of method was necessary are mentioned in the descriptions of the types. From the third of these tubes plates were made, and from the plates cultures were isolated by transferring to agar slants. These agar slants were used for inoculations.

As soon as invigorated the cultures were inoculated into certain standard media. The media employed were dextrose, lactose, sucrose, and glycerin broths, nitrate broth, Dunham's solution, and potato, besides gelatin stabs. These media gave enough data to work out the group number as described on the Society classification card (page 91). On some occasions milk and litmus milk were also used. Throughout this work every inoculation was made in triplicate.

A few points of technique must be specially mentioned, in order that this work may be more easily compared with that of other investigators:

(1) The composition of the media is particularly important. Their exact composition is given in the table on pages 111-112. The media are like those adopted by the American Public Health Association (1912), with the following exceptions: the reaction of all media not supposed to be neutral is .5 per cent acid instead of 1 per cent; the sugar broths do not contain meat extract, but they do contain salt; the bouillon contains .5 per cent NaCl; the gelatin employed to test liquefaction is the soil-extract gelatin already mentioned, instead of the ordinary beef-extract peptone medium.

(2) Methods for making certain tests are equally important. The strict aërobes, for example, were separated from the facultative anaërobes by observing whether or not growth was produced in the closed arm of a fermentation tube containing sugar broth. This method is subject to error, particularly in the case of gas-producers; but the absence of gas-producers in this soil made the method fairly reliable for this work. Motility was determined, as a rule, by microscopical examination of young broth cultures, or on other media when motility was not observed in broth; while a modification of Loeffler's flagella stain was used in doubtful cases. Another test that differed from the standard procedure is the determination of acid production in sugar and glycerin broths. Cultures were held for two weeks and were examined at the end of four, seven, and fourteen days, respectively, by titrating with N/10 NaOH, using phenolphthalein as an indicator and comparing the results of each culture with those of a blank. Lastly, cultures in nitrate broth were examined on the tenth day, as well as on the fifth.

One procedure proved very unsatisfactory. This was the reduction of potato starch as called for by the last figure but one of the group number. Potato cultures were kept for fourteen days. The figure 1 in the group number means that at the end of this time the starch was wholly consumed; the figure 2, that it was reduced, in part at least, to dextrin; the figure 3, that no reduction took place in fourteen days. This method gave very inaccurate results, and but little weight has been laid on it in classifying the cultures.

In order to prevent contamination constant checks were maintained on the purity of the cultures. At three stages in the cultivation of each culture, plates were made: the object of the first plate was to purify the original cultures; of the second, to exclude any possible contamination received during invigoration; and of the third, made on the same day as the inoculations, to obtain colonies for description. All these plates furnished checks on the purity of the cultures. Further checks were obtained from microscopical preparations made at the same time as were the inoculations, and from careful examination, with the naked eye, of the cultures on agar slants and on potato. If any one of these tests showed beyond doubt the presence of an impurity, the results of the inoculations were discarded; while if in any two of them the purity was doubtful, the results were disregarded even though neither test alone was sufficiently definite to prove the presence of a contamination.

Arrangement of cultures.— The completion of this study for any organism gives sufficient data to enable one to figure out the group number of the American Society card, besides furnishing a few supplementary facts. After a large number of cultures have been studied, the cards can be arranged in an order dependent largely on the group number but also on some of the other data. This classifies the organisms into types more or less distinct, corresponding sometimes to species, sometimes to larger groups.

After making this classification it is possible to determine which types are present in any sample. Sometimes, when it happens that all the representatives isolated from one sort of colony in a sample prove to be of the same type, it is possible to state the approximate numbers per gram of soil in which that type occurs; oftener, however, the different cultures supposed to be the same do not agree and no such statement is possible.

As already stated, this study is merely preliminary. A complete study should include at least three more steps: (1) all the common types recognized in this preliminary extensive study should be studied intensively in order to determine how closely they correspond to botanical species; (2) these types, thus recognized, should be further studied in order to learn their most diagnostic characteristics, that each may be given a concise definition; and (3) the growth of these various types in soil should be studied in the hope of learning their relation to the transformation of plant-food. This work must be left to the future.

Possibility of error.— There are two considerable possibilities for error in this work — insufficient mixing of the soil, and air infection. Poor mixing of the soil can have affected the quantitative results only, and cannot have caused much error even there because it was found that different samples of the same soil, sampled as in this work, agreed very closely in bacterial content. Air infection may have caused error in both the quantitative and the qualitative results. Quantitatively its effects must have been slight, for plates made from sterile soil by exactly the same methods showed few or no colonies. Qualitatively an appreciable error is possible either because the colony selected from the original plate was a chance air infection or because the culture became contaminated during subsequent study. This error, however, is almost excluded from this work, not only because of the care taken in detecting contaminations, but also because no culture was isolated from any sort of colony occurring only once, or even twice, on the original plates and because no type of organism was included in the results if but a single representative of it was studied. The best proof, probably, that no serious error of either sort occurred is the great similarity, both quantitatively and qualitatively, between the results of the two years.

DESCRIPTION OF SOIL

The soil sampled in these experiments is a Dunkirk clay loam. The two plats chosen for this work, 1B and 4B, are about twenty feet apart. Two spots in each plat — one in the middle, the other at the end of the plat — were chosen for sampling and were carefully marked. The samples taken from any one of these four spots must have all been from within a circle of six-inch radius.

On plat 1B are produced crops noticeably inferior to those produced on plat 4B; and this difference persists even in the greenhouse, provided the soil has been taken from the field without aëration. Not only is this true for the two plats sampled, but also for much of the soil in the immediate neighborhood of each; yet in chemical composition the two soils are essentially the same. The chief difference between the soils is in structure, the poorer soil being more compact than the other. It happens that the soil of plat 1B is finer in texture than that of plat 4B; but, since this textural difference does not hold for the rest of the soil within the two areas, it can hardly be associated with the difference in productivity.

Throughout this experiment, and during the preceding year, the soil was cropped continuously with millet. The soil was unfertilized, having received no manure nor fertilizer for at least three years before the sampling was begun. During the two years of the experiment and the year pre-

ceding, the soil had remained unplowed; but it was disk-harrowed before seeding to millet in June, 1909, and in both May and June, 1910.

WEATHER

The weather conditions throughout the course of this experiment have been tabulated and are given at the end of this article (pages 108 to 111). The tables show the average atmospheric temperature per week during the whole period; the average soil temperature throughout all the time except for parts of the fall and winter in 1909–1910; the amount of rain per week, with the days of greatest rainfall; and the moisture content of the soil at the time of sampling. While the ground is snow-covered, snowfall is not recorded and only those rains are shown which were sufficient to melt most of the snow; and thaws are mentioned instead of the days of precipitation, since the actual date of snowfall is of little importance for an understanding of soil conditions. The atmospheric temperature and the rainfall are based on the data of the United States Weather Bureau, Ithaca Station; the soil temperature is obtained from combined readings of soil thermometers set up in the plats sampled, and of a thermograph located at a distant part of the field. In order to make this more graphic the same data are plotted in plates VIII and IX (pages 80 to 83).

On April 17, 1909, the date of the first sampling, the soil had not yet dried out from winter. The spring was late and the weather was still very cold. By May 25 the soil was fairly dry. The sample taken on July 16 was taken after four weeks of extremely dry weather, although a light rain on the preceding day had brought the moisture content up to 16 per cent. In the second week in September the summer drought was broken, and the sample of September 16 was taken about a week after the rains had begun. The moisture content of this sample, however, would not have been so high as 25 per cent, were it not for the fact that rain had been falling for a few hours just before the sample was taken. In October the weather was much the same but somewhat colder. In November the weather was so cold that the soil was partially frozen about the 15th; the sample taken on the 23d, however, followed two days of moderate rain which had completely thawed the soil. January and February, 1910, were very cold months without any thaw sufficient to melt all the snow; in fact, from the middle of December until the first of March the ground was continually snow-covered. On January 21, 1910, the soil was frozen only to a depth of perhaps three inches, so that the sample taken on that day included both frozen and unfrozen soil; the samples of February, however, were taken from soil frozen to their entire depth. With the first of March a sudden change in the weather occurred, the snow disappearing in a little over a week. Drainage progressed during the first two weeks with extreme

rapidity, and by March 25 the soil was fairly dry. The conditions at this time were more advanced than at the time when the April sample of 1909 was taken. The remainder of March, 1910, and the first two weeks of April were weeks of very warm, dry weather for that time of year. In spite of this weather the moisture content of plat 4B was higher on April 15 than on March 25, while that of plat 1B was not greatly lower.

The spring of 1910 was rather unusual. After the exceptionally warm and dry weather of March the temperature remained nearly constant until into June, while immediately after the April sample was taken rains commenced. The rainfall of the next two months was somewhat above normal, although by no means so much above as it had been below normal in March. During this wet period the May sample was taken, and just at the close of the period the June sample was obtained. There was almost no rain from this date until July 2, when the next samples were taken; meanwhile the weather had been extremely hot. Slight rains and very hot weather continued during July, and slightly cooler weather occurred in August and September. The moisture content of the samples on September 21 would possibly have been lower but for a rain on the 13th. Heavier rains now commenced, so that the moisture on October 12 was as high as that shown by the September samples although the last rain had been on October 7. With the first of November the temperature dropped considerably, this month proving as exceptionally cold and stormy as March had been warm and clear. Snow or rain fell almost every day in November; on the day of sampling (November 12) there was snow on the ground which had fallen the preceding day, but the ground was soft beneath it. At the next sampling (November 30) the ground was still unfrozen, but it was covered with snow which had begun to fall in the form of rain two days before and which on the preceding day was melting nearly as fast as it fell. A few days later the soil began to freeze, and it was frozen to a depth of two or three inches on December 19, when it was next sampled. Very cold weather followed this until December 28, when two rainy days occurred during which part of the snow was melted; after two more very cold days a thaw set in which lasted intermittently throughout January, 1911, and part of February. On January 2 the ground was nearly bare; at this date the snow on plat 4B had melted completely, while on plat 1B, protected by a thin layer of ice on its surface, the soil remained partly frozen. The next day was cold and snowy. When the samples of January 4 were taken there was considerable snow on the ground and the soil was frozen about an inch and a half deep. During the remainder of the month the ground remained bare most of the time and the soil was at no time stiffly frozen, although after January 2 neither plat became completely thawed. February, unlike January, was exceptionally snowy,

although this month also was warm. The first snowfall of February occurred after a few cold days, so that the ground had become frozen and then, protected by the snow, remained frozen throughout the month in spite of a few rather severe thaws. Both samples taken this month were taken from soil that was frozen stiff. March was really a colder month than February, and the soil taken on March 3 was frozen nearly as hard as that taken on February 22. During the middle of the month there were several partial thaws, but not until a little before the sample of March 29 was taken did the soil become entirely free from frost. During the cool, rainy weather of the latter part of this month the soil did not dry out quickly, and on April 12, when the last samples were taken, although spring conditions had fairly begun the season was not so far advanced as it had been at the time when the March samples of 1910 were taken.

QUANTITATIVE RESULTS

In Table 10 are listed the quantitative results obtained by the methods described above, and in plates VIII, IX, and X they are shown graphically. In plates VIII and IX the results are compared with the weather conditions during the two years, and in Plate X with the moisture content of the soil samples. There are several points of interest:

1. During the warm weather plat 1B (the poorer soil) is generally the higher in bacteria content.

2. In the winter of 1909–1910 plat 4B is generally the higher in bacteria content. In the following winter plat 4B is the higher during December, just as in the first year; but after the thaw in January, 1911, which had more effect on plat 4B than on plat 1B, the relation is usually the opposite.

3. The highest counts were made in the winter months; the lowest numbers were found in spring and late fall. This matter has been discussed by the writer elsewhere (1912). In winter the count has been lowered during thaws.

4. There is no constant relation between the germ content and the temperature.

5. The parallelism between numbers of bacteria and the moisture content is strikingly close except in winter, when there seems to be no relation between them. In spite of this parallelism, plat 1B, which usually has the lower moisture content, generally contains the greater number of bacteria.

A few points must be mentioned in which these quantitative results may be in error. In the case of the April and May samples in 1909 the medium 2.12 was used (page 111); since this medium was subsequently found to give a lower count than the one finally adopted, the counts for these two months should probably be higher. In the case of the Sep-

TABLE 10. BACTERIA PER GRAM OF DRY SOIL

Date	Plat 4B (good)		Plat 1B (poor)	
	Center	North end	Center	North end
Apr. 17, 1909	7,000,000	. . .	18,000,000	. . . . .
May 25, 1909	3,300,000	. . . .	10,000,000	.
July 16, 1909	5,000,000	. . .	4,500,000	. . . . .
Sept. 16, 1909	10,000,000	. .	*22,000,000	. . . . . .
Oct. 8, 1909	9,200,000		8,000,000	. . . . .
Nov. 23, 1909	6,800,000	. . . . .	5,750,000	. . . . . .
Jan. 21, 1910	10,000,000	. . . .	13,000,000	. . . .
Feb. 7, 1910	23,500,000	. . . .	. . . .	. .
Feb. 26, 1910	33,000,000	. . . . .	27,000,000	. . . . .
Mar. 25, 1910	5,700,000	. . . .	6,700,000	. . . . .
Apr. 15, 1910	12,000,000	7,000,000	2,500,000	2,000,000
May 28, 1910	7,000,000	. . . .	12,000,000	. . . .
June 15, 1910	14,000,000	. . . .	16,500,000	. . . .
July 2, 1910	13,000,000	. . . .	9,000,000	. . . .
Aug. 20, 1910	8,500,000	. . . .	15,000,000	. . . .
Sept. 21, 1910	9,500,000	7,000,000	13,000,000	7,000,000
Oct. 12, 1910	. . . .	4,000,000	. . . .	6,000,000
Nov. 12, 1910	. . . .	9,500,000	. . . .	5,900,000
Nov. 30, 1910	. . . .	7,000,000	. . . .	7,000,000
Dec. 19, 1910	. . . .	23,000,000	. . . .	17,500,000
Jan. 4, 1911	. . . . . .	15,500,000	. . . .	20,000,000
Jan. 21, 1911	. . . .	15,000,000	. . . .	10,000,000
Feb. 8, 1911	. . . .	†14,000,000	. . . .	27,000,000
Feb. 22, 1911	. . . .	23,000,000	. . . .	21,000,000
Mar. 3, 1911	. . . .	22,000,000	. . . .	28,000,000
Mar. 29, 1911	. . . .	†16,000,000	. . . .	7,500,000
Apr. 12, 1911	. . . .	14,000,000	. . . .	20,000,000

* This count is probably too high, since little but surface soil was taken for the sample.
† These counts are somewhat doubtful because of the extremely rapid liquefaction of the plates.

tember sample of the same year, moreover, there was great chance of error from a different source; for, since no auger was available at the time when this sample was desired, the soil was taken by other means and could not have been so representative of the actual field conditions as a sample taken with the auger. Of plat 1B on this date, it is recorded in the notes that the soil was taken by *scraping around the hole left from the previous sampling*. This soil, therefore, must have been better aërated than that usually taken, which may explain the high numbers of bacteria found in plat 1B in September, 1909. In case this determination is an error, all samples taken during warm weather contained relatively few bacteria. Similarly, on April 12, 1911, plat 1B had cracked in drying, and the sample came partly from beside a crack; it is possible, therefore, that the high count made for this plat may be due to the better aëration of the soil selected.

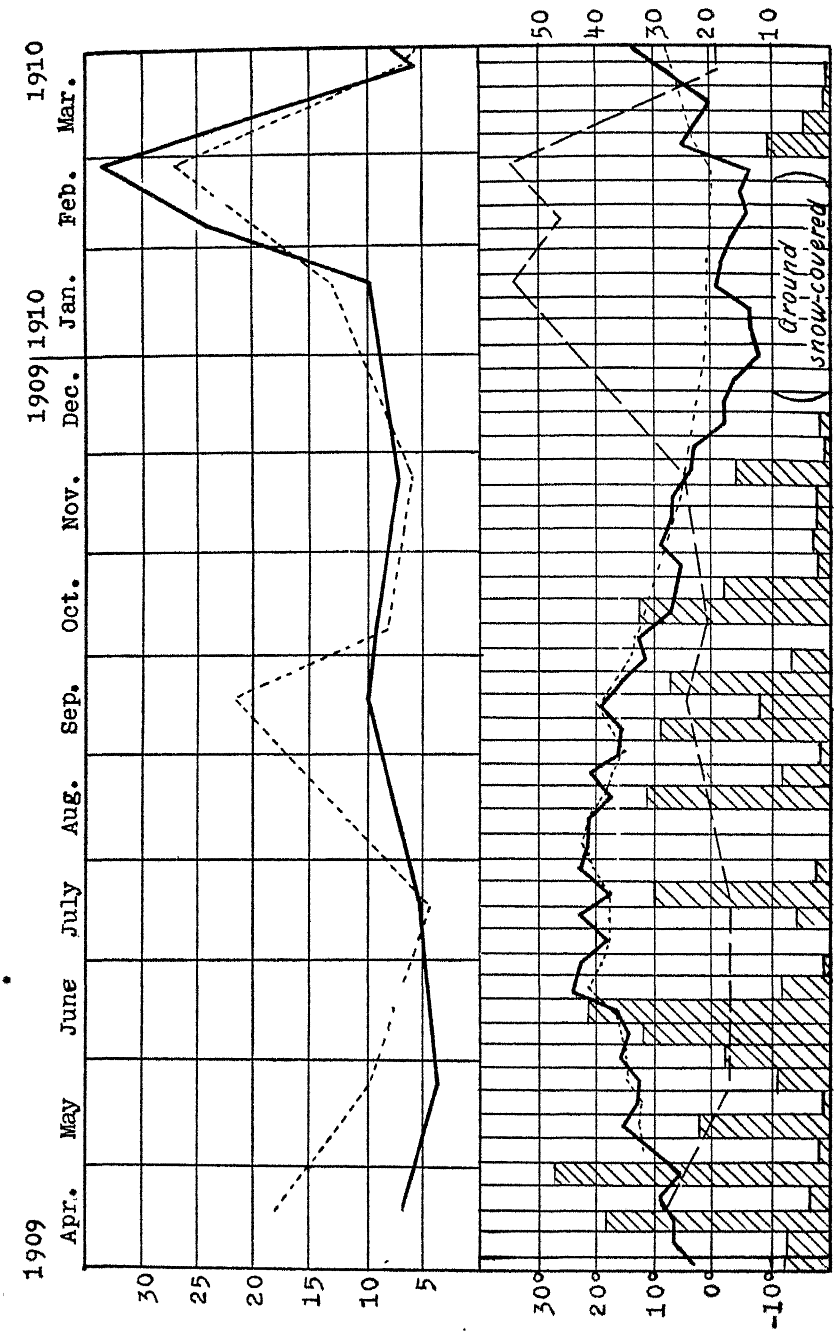

1909
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
1909 | 1910
Jan.
Feb.
Mar.
1910
30
25
20
15
10
5
30°
20°
10°
0°
-10°
50
40
30
20
10
Ground snow-covered

PLATE VIII.—*Quantitative results, 1909–1910, compared with weather conditions during the year*

Upper curves:

Bacteria in millions per gram of dry soil

—— *in plat 4B (good)*

- - - - *in plat 1B (poor)*

Lower curves:

— — *Moisture in soil samples (percentage)*

—— *Atmospheric temperature (degrees Centigrade); average per week*

- - - - *Soil temperature (degrees Centigrade); average per week*

Shaded columns represent rainfall per week, in millimeters

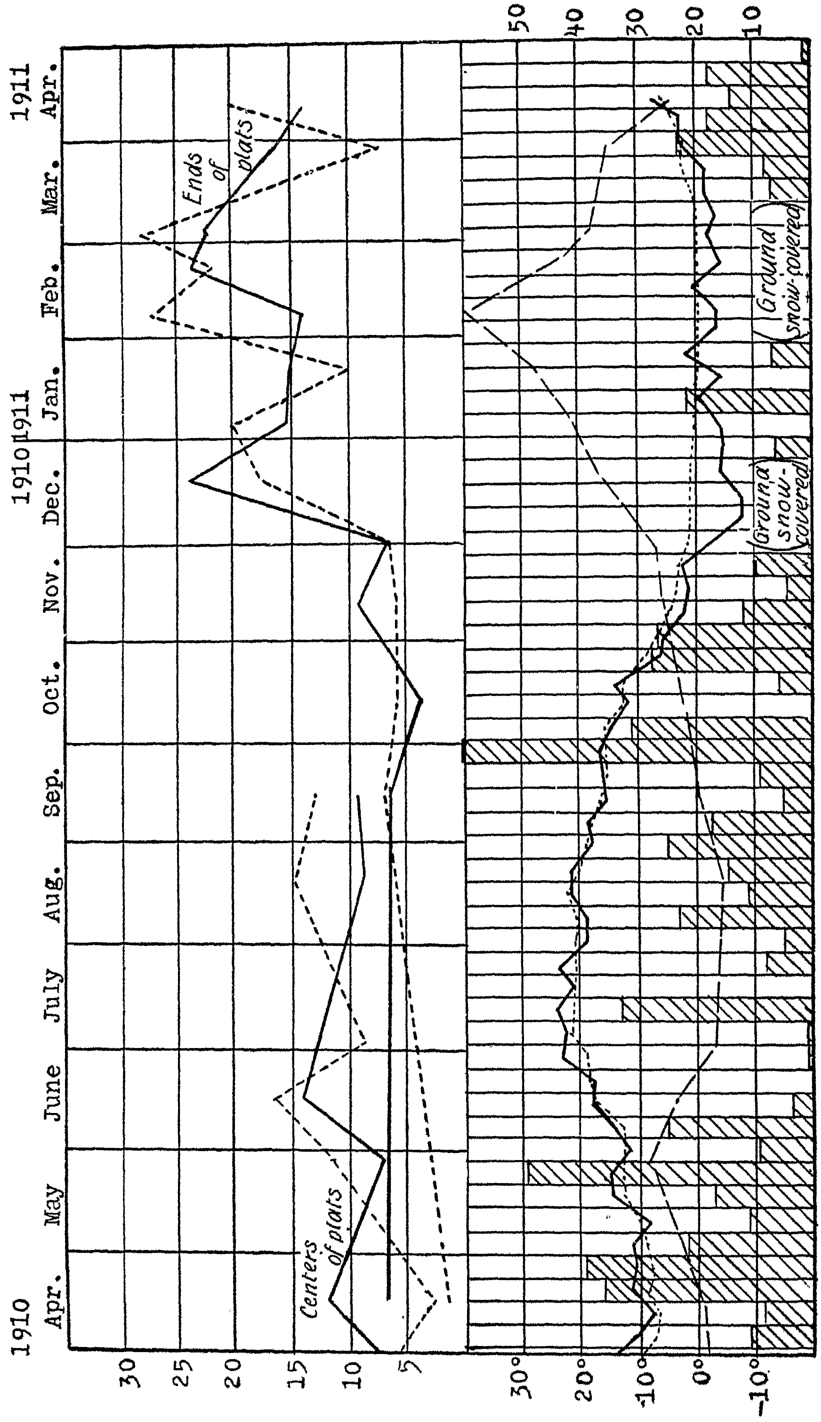

1910
Apr.
May
June
July
Aug.
Sep.
Oct.
Nov.
Dec.
1910 1911
Jan.
Feb.
Mar.
Apr.
1911
30
25
20
15
10
5
Ends of plats
Centers of plats
30°
20°
10°
0°
-10°
50
40
30
20
10
Ground snow-covered
Ground snow-covered

PLATE IX.—*Quantitative results, 1910–1911, compared with weather conditions during the year*

Upper curves:

Bacteria in millions per gram of dry soil

—— *in plat 4B (good)*

- - - - *in plat 1B (poor)*

(Short curves represent samples from centers, long curves those from ends, of plats)

Lower curves:

— — *Moisture in soil samples (percentage)*

—— *Atmospheric temperature (degrees Centigrade); average per week*

- - - - *Soil temperature (degrees Centigrade); average per week*

Shaded columns represent rainfall per week, in millimeters

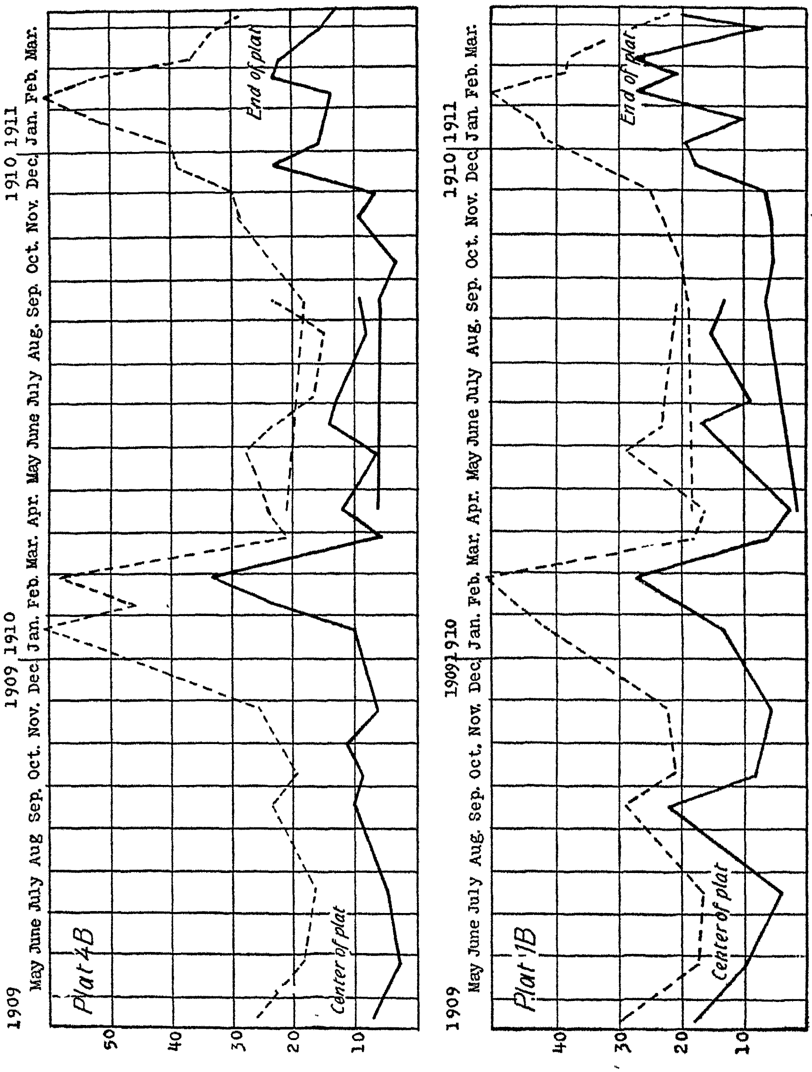

Plat 4B
Plat 1B
End of plat
Center of plat
1909
1910
1911
May June July Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar. Apr. May June July Aug. Sep. Oct. Nov. Dec. Jan. Feb. Mar.
50
40
30
20
10

PLATE X.—*Quantitative results for the two years, compared with moisture content of the individual samples. Curves beginning in April, 1909, represent samples from centers, those beginning in April, 1910, represent samples from ends, of plats*

—— *Bacteria in millions per gram of dry soil*

- - - - *Moisture content of soil samples*

Relative numbers of rapid liquefiers, Actinomyces, and slow growers

Before any cultures were isolated the colonies on the plates were always classified into three groups — rapid liquefiers, Actinomyces, and slow growers.

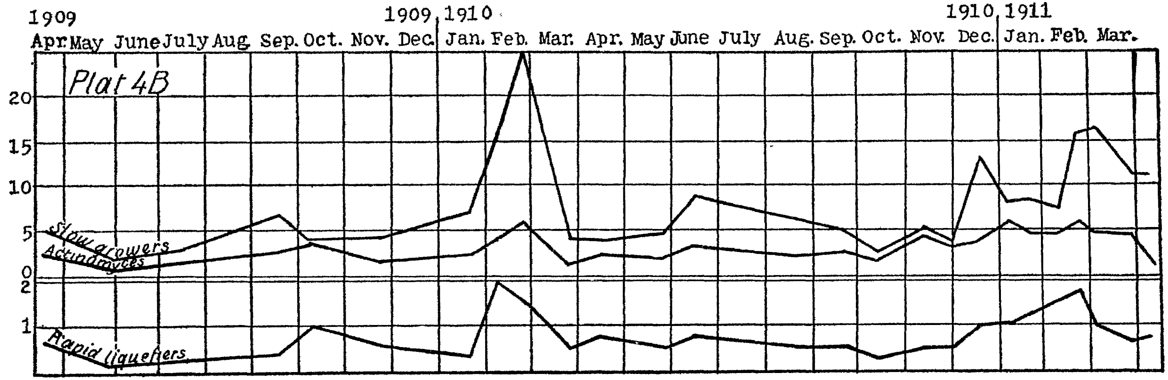
The rapid liquefiers were easily distinguished and were all put in one group, whether or not they produced spores. The Actinomyces could sometimes be recognized by their pigment production or their mildewy appearance; but in most cases a microscope was needed in order to detect their characteristic radiate structure. All the punctiform colonies besides the Actinomyces were grouped as slow growers.

This classification of the colonies is essentially the same as that employed by Hiltner and Störmer (1903), although the groups recognized by those investigators were called liquefiers, non-liquefiers, and Streptothrix. Their Streptothrix group, of course, is the same as that to which is here given the name Actinomyces. Their group of non-liquefiers must correspond closely to that of slow growers recognized in this work; for, although most of the slow growers studied here have proved to be liquefiers, the liquefaction is so slow that it can rarely be detected on the original plates even by methods as careful as those of Hiltner and Störmer. Their third group, therefore, cannot be very different from the rapid liquefiers recognized here. So this classification should give results comparable with those of the two earlier investigators.

In Table 11 are given both the absolute and the relative numbers of these three groups. The same data are shown in graphic form in plates XI and XII. There is no pronounced difference between the two plats but there are certain significant relationships, as follows:

TABLE 11. NUMBERS AND PERCENTAGE OF RAPID LIQUEFIERS, ACTINOMYCES, AND SLOW GROWERS

	Plat 4B (good)						Plat 1B (poor)					
	Rapid liquefiers		Actinomyces		Slow growers		Rapid liquefiers		Actinomyces		Slow growers	
	Number per gram of soil	Per-cent-age	Number per gram of soil	Per-cent-age	Number per gram of soil	Per-cent-age	Number per gram of soil	Per-cent-age	Number per gram of soil	Per-cent-age	Number per gram of soil	Per-cent-age
1909												
April 17	700,000	11	900,000	14	5,000,000	75	900,000	5(?)	900,000(?)	5(?)	16,000,000	90(?)
May 25	150,000	5	800,000	27	2,000,000	68	2,000,000	21(?)	500,000(?)	5(?)	7,000,000	74(?)
July 16	250,000	5	1,500,000	32	3,000,000	63	500,000	11	1,600,000	35	2,500,000	54
September 16	400,000	4	2,700,000	28	6,500,000	68	350,000	2	5,200,000	24	16,000,000	74
October 8	1,000,000	11	3,800,000	43	4,000,000	46	1,000,000	12	3,500,000	44	3,500,000	44
November 23	600,000	10	1,500,000	25	4,000,000	65	450,000	8	900,000	17	4,000,000	75
1910												
January 21	300,000	3	2,200,000	23	7,000,000	74	300,000	3	2,000,000	18	9,000,000	79
February 7	2,000,000	9	4,000,000	18	16,000,000	73	....	....	......	....	....	....
February 26	1,500,000	5	6,000,000	18	25,000,000	77	1,000,000	4	3,500,000	13	22,000,000	83
March 25	500,000	9	1,200,000	21	4,000,000	70	500,000	8	800,000	13	5,000,000	79
April 15, middle	1,000,000	8	3,000,000	25	8,000,000	67	450,000	18	850,000	34	1,200,000	48
April 15, end	750,000	11	2,300,000	32	4,000,000	57	160,000	8	500,000	26	1,300,000	66
May 28	500,000	7	2,000,000	29	4,500,000	64	800,000	7	2,500,000	21	8,500,000	72
June 15	750,000	6	3,500,000	26	9,000,000	68	750,000	5	4,500,000	28	11,000,000	67
August 20	500,000	6	2,000,000	23	6,000,000	71	600,000	4	3,500,000	23	11,000,000	73
September 21, middle	700,000	8	2,500,000	27	6,000,000	65	450,000	3	3,800,000	30	8,500,000	67
September 21, end	450,000	6	2,700,000	38	4,000,000	56	350,000	5	2,800,000	39	4,000,000	56
October 12	250,000	6	1,500,000	38	2,200,000	56	200,000	3	1,850,000	29	4,400,000	68
November 12	500,000	5	4,300,000	44	5,000,000	51	200,000	3	2,300,000	39	3,500,000	58
November 30	500,000	7	3,000,000	43	3,500,000	50	200,000	3	2,500,000	36	4,200,000	61
December 19	1,000,000	4	7,800,000	36	13,000,000	60	900,000	5	5,000,000	28	12,000,000	67
1911												
January 4	1,000,000	7	6,000,000	40	8,000,000	53	850,000	4	4,600,000	24	14,000,000	72
January 21	1,200,000	8	5,000,000	34	8,500,000	58	380,000	4	3,200,000	32	6,500,000	64
February 8	1,500,000	11	4,800,000	35	7,500,000	54	650,000	3	5,500,000	20	21,000,000	77
February 22	1,700,000	7	5,500,000	24	16,000,000	69	1,400,000	7	4,700,000	22	15,000,000	71
March 3	1,000,000	4	4,800,000	22	16,500,000	74	850,000	3	4,800,000	17	22,000,000	80
March 29	700,000	4	4,800,000	29	11,000,000	67	400,000	5	1,600,000	22	5,500,000	73
April 12	750,000	5	2,100,000	15	11,000,000	80	600,000	3	1,800,000	9	18,000,000	88



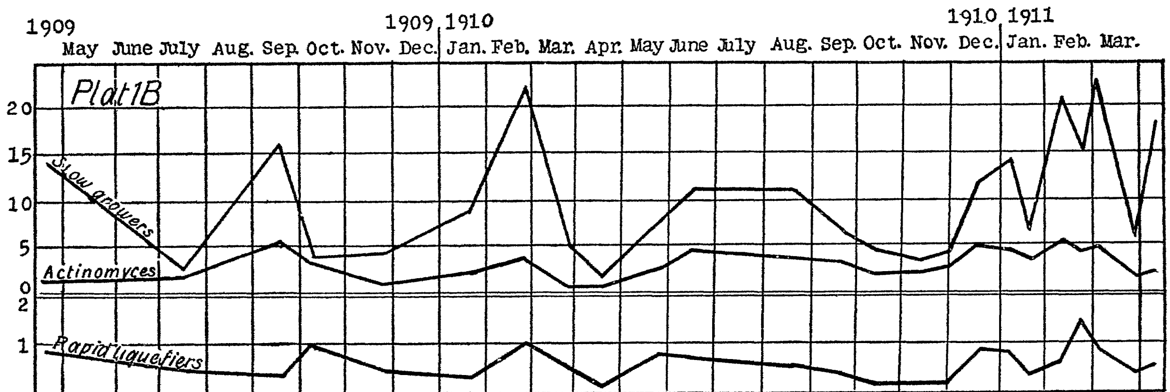


PLATE XI.—*Numbers of rapid liquefiers, Actinomyces, and slow growers. All curves indicate millions per gram of dry soil (rapid liquefiers are plotted on a scale five times as great as others). Results for first two samples of plat 1B were uncertain*

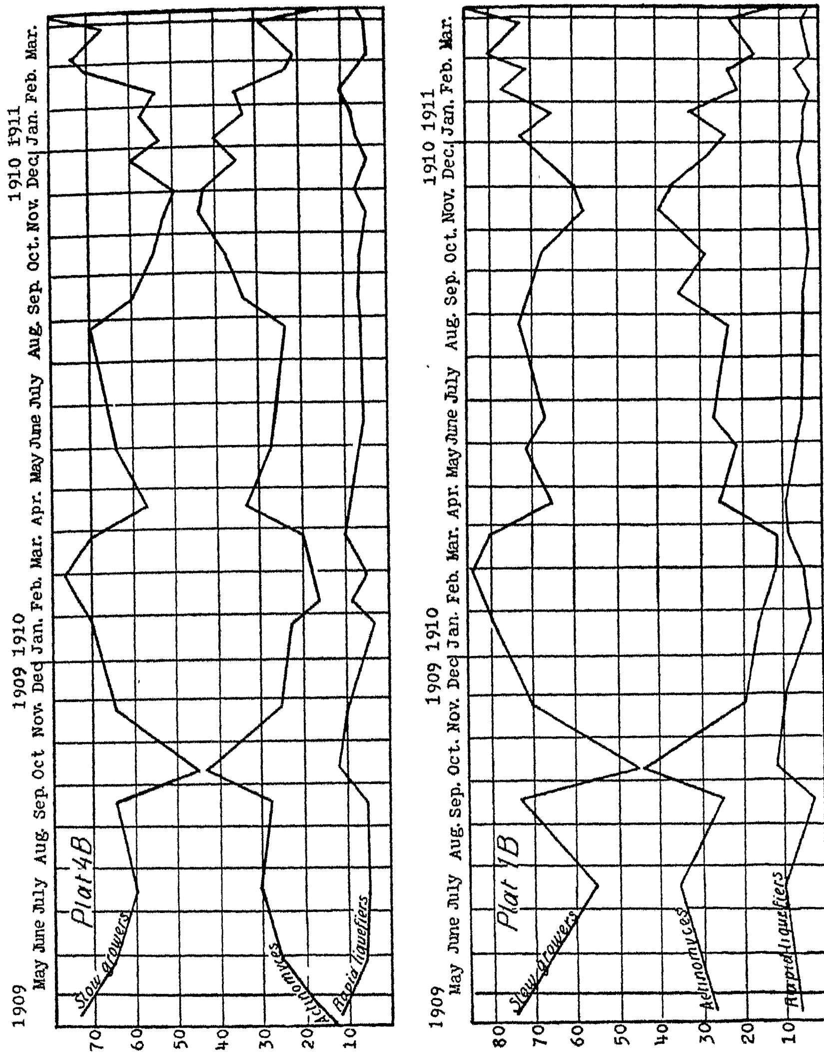


PLATE XII.—*Relative numbers of rapid liquefiers, Actinomyces, and slow growers. Curves indicate the percentage of each group occurring in the various samples. Results for the first two samples of plat 1B were uncertain*

1. Rapid liquefiers comprise but a very small proportion of the total soil flora In both absolute and relative numbers they are usually slightly higher in plat 4B (the more productive) than in plat 1B.

2. Actinomyces comprise about 15 to 44 per cent of the total flora. In absolute numbers they are almost the same in the two plats, although because of the higher total bacteria count in plat 1B they are somewhat lower in percentage in that plat.

3. Slow growers comprise 44 to 90 per cent of the total flora. In both absolute and relative numbers they are usually considerably higher in plat 1B than in the better and less compact soil of plat 4B. The difference between the two plats in total numbers lies wholly in this group.

4. These slight differences between the two plats are more pronounced in the latter part of the work than at the beginning. In plat 1B there is a gradual but fairly constant decrease in the percentage of rapid liquefiers and an increase in the percentage of slow growers, less pronounced yet noticeable in the long run; while in plat 4B such a change can scarcely be detected. The significance of this lies in the fact that during the course of the experiment the plats were not cultivated and plat 4B, which even at the outset had the looser structure, did not become compact so rapidly as did the poorer soil of plat 1B.

5. There is a tendency toward seasonal variation. The slow growers reach their highest percentage in winter, the other groups during the warmer weather. The severe thaw of January, 1911, had the effect of reducing the numbers of slow growers until the relations of the groups are about as in summer. In plat 1B this group seems to have recovered from the effects of the thaw much more quickly than in plat 4B. This different behavior of the slow growers in the two plats is probably due, not to any inherent difference between the soils, but rather to the fact that for a few days plat 4B was completely thawed, while the frost was not wholly out of plat 1B at any time during this thaw.

QUALITATIVE RESULTS

Methods of stating results

About five hundred cultures, isolated and studied by the methods above described, have been classified into thirty-five types. The classification is not carried far enough, however, to recognize actual biological species. Bacteriological technique is still too imperfect to define species successfully except in the case of a few of the most striking organisms. Some of the types described in this bulletin may be synonymous with species, but oftener they represent larger groups. They are physiological types rather than biological species.

Descriptions of these types are given in the appendix to this bulletin. Whenever possible to identify them with species already described, the name and the authority are given. Oftener, however, either because of the incomplete descriptions given to species already named or because of the different methods employed by earlier workers, identity has been impossible to establish. In such cases no new names have been assigned. Names would be of little use, because many of the types mentioned here are distinguished by too few positive characteristics to be of value as anything but preliminary groupings — type 28, for example, having, with two exceptions, wholly negative characteristics. For this reason, unfortunately, it has been necessary to denote most of the types by number alone.

The purpose of this classification is to facilitate diagnosis rather than to point out possible relationships. As already stated, the system used is that of the American Society of Bacteriologists. With the exception of motility, spore-production, and size, this system lays stress wholly on physiological characteristics. The most important features are recorded graphically by a numerical system, each organism being given its proper symbol according to the system of Migula as well as a number of ten digits based on the most diagnostic characteristics. This is called the group number and is as follows:

100.	Endospores produced
200.	Endospores not produced
10.	Aërobic (strict)
20.	Facultative anaërobic
30.	Anaërobic (strict)
1.	Gelatin liquefied
2.	Gelatin not liquefied
0.1	Acid and gas from dextrose
0.2	Acid without gas from dextrose
0.3	No acid from dextrose
0.4	No growth with dextrose
.01	Acid and gas from lactose
.02	Acid without gas from lactose
.03	No acid from lactose
.04	No growth with lactose
.001	Acid and gas from saccharose
.002	Acid without gas from saccharose
.003	No acid from saccharose
.004	No growth with saccharose
.0001	Nitrates reduced with evolution of gas

.0002	Nitrates not reduced
.0003	Nitrates reduced without gas formation
.00001	Fluorescent
.00002	Violet chromogens
.00003	Blue chromogens
.00004	Green chromogens
.00005	Yellow chromogens
.00006	Orange chromogens
.00007	Red chromogens
.00008	Brown chromogens
.00009	Pink chromogens
.00000	Non-chromogenic
.000001	Diastasic action on potato starch, strong
.000002	Diastasic action on potato starch, feeble
.000003	Diastasic action on potato starch, absent
.0000001	Acid and gas from glycerin
.0000002	Acid without gas from glycerin
.0000003	No acid from glycerin
.0000004	No growth with glycerin

At the head of each description in the appendix will be found the Society's group number corresponding to the organism described. This denotes the most distinctive features of the type, while the other important characteristics are given in the brief description that follows. In order to aid in the identification of any unknown organism with one of these types, the features are tabulated in the form of a key (facing page 100).

Kinds of organisms found

The organisms fall into six groups: (1) rapid-liquefying, peritrichic, spore-bearing, large rods (the *Bacillus subtilis* group); (2) rapid-liquefying, monotrichic or lophotrichic, non-spore-bearing, small rods (the *Pseudomonas fluorescens* group); (3) slow-liquefying, non-spore-bearing, small rods; (4) non-liquefying, non-spore-bearing, small rods; (5) cocci, usually non-liquefying; (6) Actinomyces. In the classification of colonies already mentioned, groups 1 and 2 were included in the rapid liquefiers and groups 3 to 5 in the slow growers.

Of the first five groups, 1 and 2 were always present in small numbers, 3 comprised over half of the flora of every sample, while members of groups 4 and 5 were fairly rare; group 6 was always found in large numbers. In other words, the most common organisms were slow liquefiers and the least abundant were non-liquefiers.

No gas-producers were observed. This is striking, for they are very abundant in nature. The only gas-producers obtained from this soil have been isolated from plates grown in an atmosphere of hydrogen, in the course of some work not included in this report.

Acid-producing non-liquefiers are likewise absent. This is also significant, for in milk they are very important.

Facultative anaërobes are rare. By the methods employed practically none but *Bacillus subtilis* and *B. mycoides* can grow in the absence of oxygen. This is not surprising, for, compared to milk and water, soil is an unusually well-aërated medium.

Immotile forms are very abundant. This also is not very surprising, for the films of moisture in the soil cannot allow great motility.

In all these respects it will be seen that the flora of soil differs widely from that of milk, of water, or of any other natural medium that has yet been studied.

Occurrence of the types

The samples in which the various types were found are shown in tables 12 and 13. Wherever possible the numbers of each type per gram of soil is given. These data are necessarily incomplete, for it was necessary to base the numbers on a colony count and they could not be obtained when any two types produced indistinguishable colonies.

Most striking is the utter lack of appreciable difference between the two plats. Some types, it is true, such as 15, 32, and 37, were found only in plat 4B, while type 19 was isolated only from plat 1B; but these four types occurred so seldom that they may have been merely overlooked in the soil where they were not found. All the other types occur in both soils, and their relative abundance is about the same in each. The slight difference between the two soils noted by the classification of the colonies into liquefiers, non-liquefiers, and Actinomyces, is not noticeable when the individual types are considered. This means either that the two soils contain the same kinds of organisms, or that our technique is too imperfect to distinguish the differences. Possibly if accurate data could be obtained as to the relative abundance of the various types, a greater difference might be observed.

TABLE 12. OCCURRENCE OF RAPID LIQUEFIERS

	Plat 4B								Plat 1B							
	Bacillus subtilis group															
Type	1	2	3	4	5	6	7	9	1	2	3	4	5	6	7	9
1909																
Apr. 17	150	250	...	...	...	...	...	..	150	350	.	...	Tr.		25	..
May 25	80	18	...	...	..	...	...	Tr.	70	60?	...	...	Tr.	.	..	..
July 16	125*	100*	...	...	...	...	...	.	50	400*	...	.	.	..	Tr.	.
Sept. 16	70*	200*	..	..	...	...	...	...	70*	200*	...	...	.	.	...	..
Oct. 8	70	?	400	...	...	...	...	...	60	?	700	..	..	..	.	.
Nov. 23	200*	100?*	Tr.	...	...	Tr.	...	...	40*	200?*	..	...	..	..	.	...
1910																
Jan. 21	100*	...	...	...	..	50	...	...	50*	...	...	...	..	100	...	..
Feb. 26	200	...	...	...	Tr	150	Tr	...	100	...	.	..	Tr.	250	..	..
Mar. 25	120*	...	...	...	...	125	Tr.	..	100*	...	100?	Tr.	..	50	...	...
Apr. 15 middle	200*	250	...	..	...	...	400	...	30*	220	...	...	..	200	.	...
Apr. 15 end	100*	250	...	...	...	...	100	.	10*	150	..	..	...	Tr.	..	...
May 28	100*	200*	...	...	...	100*	...	..	100*	350*	..	...	...	200	..	.
June 15	150*	200*	...	...	...	100?	100?	..	100*	180	...	...	..	...	300?	..
Aug. 20	300*	Tr.	...	...	...	...	...	...	100*	300*	...	...	...	100?	100?	...
Sept. 21 middle	200*	250*	...	...	...	100?	50*	...	40*	150?	...	...	...	?	75?	...
Sept. 21 end	150*	180*	...	...	..	120?	?	..	35*	150*	...	...	...	100?	Tr.	..
Oct. 12	75*	...	...	...	...	Tr.?	?	..	40*	...	...	...	..	Few	...	...
Nov. 12	150*	(100)	...	...	...	175?	50?		20*	...	...	...	...	70*	...	..
Nov. 30	150*	...	...	...	...	100?	100?	...	Tr.	...	...	...	..	75?	75?	...
Dec. 19	Tr.	(175)	...	...	...	50	...	Tr.	80*	(200*)	...	...	...	300	?	Tr.
1911																
Jan. 4	300*	?	...	?	...	150*	?	...	Tr.	?	...	?	...	350*	?	...
Jan. 21	250*	400?	..	Tr.	...	100*	?	...	60*	100	...		..	25?	25?	...
Feb. 8	200*	...	...	300	...	Pres.	Pres.	.	60*	...	...	100?	...	250	Tr.	..
Mar. 3	150*	(100?)	...	100?	...	150?	150?	...	150*	...	..	150?	...	150?	?	..

	Plat 4B								Plat 1B							
	Pseudomonas fluorescens group															
Type	10	11	12	15	16	17	18	20	10	11	12	16	17	18	19	20
1909																
Apr. 17	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...
May 25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
July 16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sept. 16	...	...	...	...	70	...	30	...	...	...	...	120	...	30	...	...
Oct. 8	Tr.	...	...	50?	120	Pres.	50?	...	...	...	...	Tr.	...	...	...	...
Nov. 23	...	...	...	...	100	...	100	..	...	...	...	...	...	...	...	...
1910																
Jan. 21	...	...	...	...	100	...	...	...	...	...	...	...	...	...	...	...
Feb. 26	150	80	..	...	80	...	...	...	80	...	..	...	...	...	...	...
Mar. 25	...	Tr.	...	...	...	...	...	...	...	...	..	..	...	...	...	...
Apr. 15 middle	Tr.	...	...	...	10	...	...	...	...	Tr.	...	...	...	...	...	...
Apr. 15 end	...	...	...	...	Tr.	...	...	...	...	...	...	...	...	...	...	...
May 28	...	...	...	...	200*	...	...	..	...	...	...	160*	...	...	...	...
June 15	...	...	...	...	100	...	...	..	...	...	...	50	...	...	...	...
Aug. 20	Tr?	...	...	...	...	...	...	..	Tr?	...	...	Tr.	...	...	...	...
Sept. 21 middle	...	...	Tr.	...	Tr.	...	...	Tr.	...	...	150?	...	...	...	...	...
Sept. 21 end	...	...	...	...	...	...	...	..	...	...	...	Tr.	25	..	...	...
Oct. 12	...	...	130?	...	...	...	...	...	...	...	Tr.	...		.	...	..
Nov. 12	...	...	...	...	20*	...	...	...	...	...	...	35	.	...	40?	...
Nov. 30	...	...	...	...	...	...	...	Tr.	...	...	...	Tr.	..	..	...	..
Dec. 19	...	...	...	...	100	...	400	...	...	...	...	..	...	..	..	Tr.
1911																
Jan. 4	...	...	100	...	..	...	Tr.	...	...	...	100	Tr.	...		..	...
Jan. 21	...	...	...	...	...	...	Tr.	..	...	...	..	...	..	...	..	..
Feb. 8	...	...	...	...	...	...	...	..	...	...	..	.	...	..	...	...
Mar. 3	...	...	...	...	Tr.	...	...	...	...	...	200?	Tr.	...	..	...	...

Figures indicate thousands of bacteria per gram of soil.
" Pres." indicates, present in considerable numbers but unestimated.
" Tr." indicates, present in mere traces.
? alone indicates, occurrence doubtful.
? following a number indicates, present, but perhaps not in the abundance denoted by the number.
* indicates, no cultures isolated, estimate based on colony alone.
( ) about numbers under type 2 indicates subtype *b*; numbers not in parenthesis indicate subtype *a*.

TABLE 13. OCCURRENCE OF SLOW GROWERS

	Plat 4B							Plat 1B						
	Slow liquefiers													
Type	21	22	25	26	27	28	29	21	22	25	26	27	28	29
1909														
Apr 17	...	..	.	..	.	?	.	Pres.	.	...			?	..
May 25	..	..	.		..	Pres		.			1,000	.		
July 16	.	..	Pres.	.	..	3,000?	..	.	.	Pres.		.	Pres.	.
Sept. 16	..			.	Tr	3,000?	Tr	..				Pres.	Pres	
Oct. 8	Tr.	.	.	.	Tr.	Pres		Tr.		Tr.			10,000?	Tr.
Nov. 23	....	Tr.	Tr.	.	.	Pres	...	..			.	Tr.	Pres.	....
1910														
Jan. 21	....		...	Tr.	..	Pres.	500?	7,000?	.		.	.	...	Pres.
Feb. 26	Tr.	.	Pres.	..	..	Pres.	.	.		Pres.		Pres.	...	....
Mar. 25	....	Tr.	..	.		3,000		...	.	1,200	.	..	2,800	....
Apr. 15 middle	..	..	Pres.	.	Pres.	Pres.	.	Pres.	..	.		..	..	....
Apr. 15 end	.	.	...	.	...	Pres.	...	Tr.	.	..	?	...	Pres.	....
May 28	..	.	....	..	..	?	...	..		..	..	...	?	....
June 15	..	..	....	..	..	Pres.	...	...	..	..	.	...	10,000	....
Aug. 20	..	...	...	..	..	?	..	..	.	....	.	...	?	....
Sept. 21 middle	...	....	....	..	..	?	...	....	.		..		Pres.	Tr.
Sept. 21 end	.	...	...	..	..	Pres.	...	...	.	....	....	Tr.	4,000	....
Oct. 12	...	....	....	..	..	Pres.	Tr.	Tr.		..	..	.	4,000?	....
Nov. 12	...	....	....	..	..	Pres.	Tr.	....	..	....	...		Pres.	Tr.
Nov. 30	....	....	....	..	..	Pres.	..	...	..	....	..	..	4,000	....
Dec. 19	....	....	...	..	.	Pres.	....	....	..	....	..	.	10,000?	....
1911														
Jan. 4	....	....	....	..	..	Pres.	....	....	.	...	...	...	Pres.	....
Jan. 21	....	....	Tr.	...	...	Pres.	..	...	.	....	..	..	Pres	Tr.
Feb. 8	Pres.	....	....	...	...	Pres.	....	..	Tr.	....	.	.	Pres.	..
Mar. 3	Tr.	..	...	...	..	Pres.	..	.	..	...	..	.	Pres.	Pres.

	Plat 4B								Plat 1B					
	Non-liquefiers													
Type	31	32	33	34	35	36	37	38	31	33	34	35	36	38
1909														
Apr. 17	...	....	....	...	....	..	....	...	Tr.	...	....	....	....	.....
May 25	...	Tr.	....	...	....	...	....	....	....	Tr.	....	....	....	.....
July 16	...	Pres.	...	.	....	Tr.	....	.	....	Tr.	....	....	Pres	.....
Sept. 16	...	....	...	.	....	....	...	Tr.	....	....	....	....	....	Tr.
Oct. 8	...	....	...	..	....	...	...	...	....	...	...	...	....	....
Nov. 23	...	....	....	..	....	....	....	...	....	....	....	....	....	....
1910														
Jan. 21	...	....	....	.	...	...	....	...	...	...	....	....	....	....
Feb. 26	...	....	...		1,000	...	....	..	...	...	....	300	....	....
Mar. 25	...	....	...	..	....	...	...	..	...	..	....	....	....	....
Apr. 15 middle	...	....	...	..	....	..	....	...	...	....	....	....	....	....
Apr. 15 end	...	....	....	..	....	....	....	Tr.	...	....	.	....	....	....
May 28	...	....	....	..	....	..	....	.	...	....	....	....	....	....
June 15	Tr.	....	..	.	....	Tr.	...	....	...	....	....	....	....	....
Aug. 20	...	....	...	.	....	...	...	....	...	....	....	....	....	....
Sept. 21 middle	..	....	....	.	....	.	.	Pres.	...	..	....	....	....	....
Sept. 21 end	...	....	....	Tr.	....	...	....	...	...	....	....	....	....	....
Oct. 12	...	....	Tr.?	.	....	Tr.	Tr.	...	...	....	....	....	....	....
Nov. 12	...	....	....	Tr.	....	...	....	...	....	Tr.	...	....	....	....
Nov. 30	...	....	....	..	....	...	....	....	....	....	....	....	....	....
Dec. 19	...	....	....	..	....	...	....	....	....	....	....	....	....	....
1911														
Jan. 4	...	....	....	..	....	....	....	..	....	....	Pres.	....	....	....
Jan. 21	...	....	....	..	....	...	Pres.	..	....	Tr	..	....	Tr.	....
Feb. 8	...	....	..	..	....	...	..	..	.	..	....	....	....	....
Mar. 3	...	Tr.?	...	..	....	...	....	..	...	....	..	....	Tr.	....

Figures indicate thousands of bacteria per gram of soil.
"Pres." indicates, present in considerable numbers but unestimated.
"Tr." indicates, present in mere traces.
? alone indicates, occurrence doubtful.
? following a number indicates, present, but perhaps not in the abundance denoted by the number.
* indicates, no cultures isolated, estimate based on colony alone.

TABLE 14. SEASONAL DISTRIBUTION OF TYPES

Type number	Group number	1909 April 17	1909 May 25	1909 July 16	1909 Sept. 16	1909 Oct. 8	1909 Nov. 23	1910 Jan. 21	1910 Feb. 26	1910 Mar. 25	1910 April 15	1910 May 28	1910 June 15	1910 Aug. 20	1910 Sept. 21	1910 Oct. 12	1910 Nov. 12	1910 Nov. 30	1910 Dec. 19	1911 Jan. 4	1911 Jan. 21	1911 Feb. 8	1911 Mar. 3
1	B.121.2323023	+	+	×	×	+	×	×	+	×	×	×	×	×	×	×	×	×	Tr.	×	×	×	×
28	Bact.211.3332023	×	+	+	+	+	+	+	+	+	+	×	+	×	+	+	+	+	+	+	+	+	+
6	B.111.2223022	?					Tr.	+	+	+	+	+	+	+	+	Tr.	+	+	+	×	+	+	+
7	B.111.3332033	+		Tr.					Tr.	Tr.	+		+	+	+	?	+	+	?	?	+	+	+
16	Ps.211.2332623				+	+	+	+	+		Tr.	+	+	Tr.	Tr.		+	Tr.	+	Tr.			Tr.
2a	B.121.2323022	+	+	×	×	?	?				+	×	+	×	+						+		
31	Ps.212.2333033	Tr.											Tr.										
32	Ps.212.3333033		Tr.	+																			Tr. ?
36	Bact.212.3332034			Tr.	+								Tr.			Tr.							
25	Bact.211.3333023			+		Tr.	Tr.		+	+	+										Tr.		
29	Bact.211.3332533				Tr.	Tr.		+							Tr.	Tr.	Tr.				Tr.		+?
27	Bact.211.3332023				+	Tr.	Tr.		+		+				Tr.								
18	Ps.211.2332133				+	+	+												+	Tr.	Tr.		
20	Ps.211.3333033														Tr.			Tr.	Tr.				
34	Ps.212 3332033														Tr.		Tr.			+			
12	Ps.211.3333033														+	+				+			+
15	Ps.211.2333833					+																	
17	Ps.221.2322032					+									+								
3	B.121.2323922					+	Tr.			+													
10	Ps.211.2333023					Tr.			+		Tr.		?										
38	M.212 2332033					Tr.					Tr.				+								
21	Bact.211.3333023	+				Tr.		+	Tr.		+					Tr.						+	Tr.
37	Bact.212.2332033															Tr.					+		
33	Ps.212.3332033		Tr.	Tr.												Tr. ?	Tr.				Tr.		
22	Bact.211.3333523						Tr.			Tr.												Tr.	
19	Ps.211.2332023																+						
9	B.112.3332033		Tr.																Tr.				

+ indicates, present in considerable numbers; Tr., in mere traces; ×, probably present in considerable numbers, but none isolated.

TABLE 14 (*concluded*)

Type number	Group number	1909						1910												1911			
		April 17	May 25	July 16	Sept. 16	Oct. 8	Nov. 23	Jan. 21	Feb. 26	Mar. 25	April 15	May 28	June 15	Aug. 20	Sept. 21	Oct. 12	Nov. 12	Nov. 30	Dec. 19	Jan. 4	Jan. 21	Feb. 8	Mar. 3
26	Bact.211.2332033		+					Tr.			?												
4	B.121.2323022									Tr.										?	Tr.	+	+
35	Bact.212.3332633								+														
11	Ps.211.3333033								+	Tr.	Tr.												
5	B.111.2323022	Tr.	Tr.						Tr.														
2b	B.121.2323023	Tr.	Tr.								+		Tr.		Tr.		Tr.		+		+		+

+ indicates, present in considerable numbers; Tr., in mere traces; ×, probably present in considerable numbers, but none isolated.

The seasonal distribution of the types is shown in Table 14. In order to make this distribution as clear as possible, the types are arranged in the order of the date of the first appearance in the fall of each year. The first six types occur more or less frequently throughout the year, while the others appear only for shorter periods. The summer flora is the simpler; that of fall and winter is more complex because of the occurrence in those seasons of various types not to be found in summer. These types are largely the same for both years. The greater variety during the colder months is surprising, but it is undoubtedly associated in some way with the great numerical increase while the soil is frozen. The writer has already (1912) used this fact in trying to explain the high bacteria count of winter soil.

SUMMARY

The conclusions to be drawn from this work fall under two heads: (1) those contributing to the general knowledge of soil bacteria, and (2) those concerning the differences observed in this special case between the two plats similar in texture and in chemical composition but differing in structure and productivity.

Conclusions of a general nature

The flora of soil is quite different from that of milk, of water, or of any other natural medium yet investigated. It consists primarily of strict aërobes that do not produce spores, the majority of which liquefy gelatin very slowly and grow but poorly in the ordinary bacteriological media.

Certain types of bacteria may occur throughout the year, growing in winter and in summer alike. Others have been found for short periods only.

There is an intimate connection between the moisture content and the numbers of bacteria, but there are many times when the two do not run parallel. The most striking exception is in winter, when the germ content increases if the soil is well frozen but decreases after a thaw, even though the moisture in the soil does just the opposite.

Conclusions concerning the differences between the two plats studied

No type of bacteria found frequently in one soil has been lacking in the other.

Except during winter the total numbers of bacteria are higher in the more compact and less productive of the two plats. Since that plat has usually had the lower moisture content, this is contrary to the general relationship between bacteria and soil moisture.

The difference in total numbers of bacteria between the two plats lies wholly in the group of organisms here called slow growers. Rapid liquefiers are often even fewer in the less productive than in the more productive plat.

The qualitative differences between the two plats have increased. At the end of the experiment the relative numbers of liquefiers have decreased and those of slow growers have increased in the less productive plat; while in the other plat this tendency has been almost unnoticeable. This is interesting, because at the same time the physical differences between the two plats have been increasing, the poorer soil growing compact more rapidly than the better soil.

APPENDIX

CLASSIFICATION OF THE ORGANISMS

By means of colonies on gelatin

The gelatin colonies of the various organisms are not sufficiently distinct to serve as a basis of accurate classification; yet by means of a classification of the colonies we can learn how abundant any type is in a given soil sample. Hence the classification here used, although very rough, is useful.

1. Rapid-liquefying colonies, usually over 5 millimeters in diameter.
   - a. Colonies rhizoid. *B. mycoides.* Type 1
   - b. Colonies round, more or less concentric, with surface membrane; margins ciliate. Primarily *B. subtilis.* Type 2 also types 4 and 5
   - c. Colonies round, typically with distinct flocculent center, white or grayish in color; center sometimes smooth and less distinct. Primarily types 6 and 7 also types 3 and 4
   - d. Colonies round to irregular, without internal structure, liquefying extremely rapidly. *Ps. fluorescens* group. Types 10 to 15 and 17 to 19
   - e. Colonies round, orange, typically of radiate structure. Type 16
2. Colonies punctiform, or occasionally 1 to 2 millimeters in diameter; margins usually entire beneath microscope, never filamentous. Usually showing no liquefaction, but occasionally slightly liquefied. The slow growers. Types 20 to 39

   It is very seldom that the individual types under this group can be distinguished by their colonies.
3. Colonies punctiform to 3 or 4 millimeters in diameter, filamentous beneath microscope; if large, always tough and leathery; if on surface, sometimes covered with aërial hyphæ resembling mildew. Actinomyces. Types 40 and 45

By means of microscopic, cultural, and biochemical characteristics

The following key is of the kind usually known as an analytical key. The types are arranged in the same order as in Table 15, but only the diagnostic features are given.

Bacteria proper — rods or cocci

A. Spores produced.
- I. Rapid liquefiers. Flagella present (peritrichic, or at least not polar).
  - 1. Nitrates reduced. Flagella many.
    - a. Facultative anaerobic.
      - i. Growth rhizoid. Non-chromogenic. *B. mycoides.* Type 1
      - ii. Growth not rhizoid; rugose on agar.
        - *a.* Non-chromogenic. *B. subtilis.* Type 2
        - *b.* Pink chromogenic. On potato and gelatin stab. *B. simplex* (?) Type 3
      - iii. Growth plane; no surface growth on broth. Type 4
    - b. Strictly aërobic. Type 5
  - 2. Nitrate reduction doubtful. Flagella few. Strictly aërobic.
    - a. Acid production constant from dextrose, often from other sugars; indol produced. Type 6
    - b. Acid often not produced from dextrose, never from other sugars nor from glycerin. Indol negative. *B. megatherium* (?) Type 7
- II. Non-liquefying. Type 9

B. Spores not produced. Strictly aërobic.
- I. Liquefaction rapid; gelatin colonies large. Flagella polar. Rods under 1 micron.
  - 1. Nitrates reduced.
    - a. Non-chromogenic.

i. With a single flagellum. Type 10
ii. Flagella 2 to 6.
a. Rods under .5 micron. Type 11
b. Rods over .5 micron. Type 12
b. Reddish-brown chromogenic. Flagella 3 to 6. Type 15
c. Yellow to orange chromogenic. Probably a single flagellum. Type 16
2. Nitrate reduction doubtful. Non-chromogenic. Flagella 2 to 3. Acid from dextrose. Type 17
3. No nitrate reduction. Flagella 2 to 6. Acid from dextrose.
a. Fluorescent. *Ps. fluorescens.* Type 18
b. Non-fluorescent. Milk turned brown to green, with pungent odor. Type 19

II. Liquefaction slow; gelatin colonies punctiform.
1. Flagella polar, 3 to 6. Type 20
2. Flagella none.
a. Nitrite alone produced from nitrates.
i. Non-chromogenic. Type 21
ii. Yellow chromogenic. Type 22
b. Ammonia alone produced from nitrates. Type 25
c. Nitrates not reduced.
i. Non-chromogenic.
a. Rods sometimes over 1 micron. Acid from dextrose. Type 26
b. Rods under 1 micron. No acid from any sugar.
aa. Indol produced. Type 27
bb. Indol not produced. Type 28
ii. Yellow chromogenic. Type 29

III. Liquefaction none.
1. Flagella polar.
a. Nitrates reduced. Flagella 2 to 3.
i. Acid from dextrose. Type 31
ii. No acid from dextrose. Type 32
b. Nitrates not reduced.
i. Rods often under .5 micron. Type 33
ii. Rods often over 1 micron. Type 34
2. Flagella absent.
a. Orange chromogenic. Type 35
b. Non-chromogenic.
i. Rods under .5 micron.
a. No acid from dextrose. Type 36
b. Acid from dextrose. Type 37
ii. Micrococcus over .5 micron in diameter. Type 38

Actinomyces—filamentous forms

A. Producing leathery growth on agar, surface glistening. *Act. flavus.* Type 40
B. Growth on agar with a white powdery surface. *Act. albus.* Type 45

The accompanying table is a classification of the types belonging to the Bacteria proper. It is based on the key given above, but contains also certain information in regard to other important characteristics of the organisms.

DESCRIPTION OF THE TYPES

Spores produced

Rapidly liquefying

Type 1 *B. mycoides* Flugge, 1886 B. 121.2323023

Rods .8–1.3 by 2–6 μ. Motility very slight or none. Chains parallel; growth rhizoid. Indol usually produced. In broth flocculent; no surface growth. Gelatin colonies rapidly liquefying, rhizoid.

A very constant type; the only disagreement is in indol production. Undoubtedly identical with the well-known organism of Flügge.

Very abundant; it is rare that a soil sample has been found without it.

Type 2 *B. subtilis* Cohn, 1875 B. 121.23230$\overset{?}{2}\overset{?}{2}$

Rods .8–1.2 by 2–6 μ. Motility great. Chains not parallel. Indol very variable. Surface growth on liquid media. Gelatin colonies typically concentric, with a finely ciliate margin.

A rather variable type, particularly in size of rods and in indol production. It is possible to recognize the two following subtypes, but it seems unwise to make two separate types of them.

Subtype a. Produces acid from glycerin. Very abundant in spring and summer, but seeming to disappear almost completely in winter. About twenty-two cultures have been studied.

Subtype b. No acid from glycerin. Indol always negative. Isolated frequently from winter soil. Only fourteen cultures have been studied.

Type 3 *B. simplex*(?) Gottheil, 1901 B. 121.232$\overset{?}{3}$92$\overset{?}{2}$

Rods .8–1.5 by 2–6 μ. Motility great. Indol variable. Pellicle on liquid media. Pink chromogenisis shows only on potato and in gelatin stab, but is fairly constant. Gelatin colonies with white flocculent center surrounded by a clear liquefied zone.

Somewhat variable, particularly in size of rods, indol production, and acid production from sucrose and glycerin. There is some question whether this is the same as Gottheil's organism, since Gottheil made no mention of chromogenisis; otherwise the agreement is fairly close.

Not common, although isolated in large numbers during the fall of 1909. Ten cultures studied.

Type 4 B. 121.2323022

Rods .8–1.2 by 2–5 μ. Motility great. Indol variable. No surface growth on broth. Gelatin colonies round, liquefying, concentric, or with flocculent center.

Fairly constant, although one culture produced no acid from glycerin.

Not abundant; isolated only during the winter. Only seven cultures studied.

Type 5 B. 111.2323022

Rods .8–1.4 by 1.5–4 μ. Motility great. Indol variable. On broth, sometimes a surface ring. Gelatin colonies round, liquefying, not characteristic.

Probably not a distinct type; represented by only five cultures.

Type 6 *B. megatherium* (?) De Bary B. $111.2\overset{?}{2}2\overset{?}{3}02\overset{?}{2}$

Rods 1–1.5 by 2–6 μ. Motility very slight or none. Only one or two flagella, which are not polar. Long chains, which are not parallel. Indol produced. Growth flocculent in broth, but rather poor. Gelatin colonies with white flocculent center surrounded by a clear liquefied zone.

Fairly constant, with the exception of nitrate reduction and production of acid from lactose and glycerin.

Very abundant; isolated from every sample after the fall of 1909. About fifty cultures studied.

Type 7 B. $111.\overset{?}{3}33203\overset{?}{3}$

Rods .8–1.4 by 2–6 μ. Motility very slight or none. Only one or two flagella, which are not polar. Long chains, which are not parallel. Indol negative. Growth flocculent in broth, but rather poor. Gelatin colonies with white flocculent center surrounded by a clear liquefied zone.

Fairly constant, except for acid production from dextrose (although one culture reduces nitrates). Much like type 6, but distinguished from that type by its failure to produce indol or to produce acid from any sugar except sometimes dextrose.

Fairly abundant, having been isolated from most of the samples. About thirty cultures studied.

Non-liquefying

Type 9 B. (?) 112.3332033

Rods .4–.7 by .5–2 μ. Motility slight. Arrangement of flagella not studied. Indol negative. No surface growth on broth. Gelatin colonies punctiform.

Only three cultures studied, but these agree fairly well. Possibly the type would be subdivided if more examples had been found.

Spores not produced; strictly aërobic

Rapid liquefiers; flagella polar

Type 10 *Ps. liquida*(?) (Frankland, 1889) Chester, 1901 Ps. $211.23330\overset{?}{2}3$

Rods .3–.7 by .6–1.5 μ. Motility great. One flagellum. No chains. Indol production feeble or none. Growth in broth variable. Gelatin colonies rapidly liquefying, structureless.

This type is not well defined and Franklin's organism is poorly described; hence the two can hardly be identified with each other.

Not abundant, only six cultures having been isolated. Appeared during fall and winter, 1909–1910, persisting into the spring.

Type 11 — Ps. 211.3333033

Rods .2–.3 by .4–1.5 μ. Motility great. Flagella 2–6. No chains. Indol positive. Usually a surface ring on broth. Gelatin colonies rapidly liquefying, structureless.

A fairly well-defined type, appearing only during the winter of 1909–1910. Only five cultures studied.

Type 12 — Ps. 211.3333033

Rods .4–.8 by .8–1.5 μ. Motility great. Flagella 2–6. No chains. Indol usually negative. Usually no surface growth on broth, but occasionally a ring or a pellicle. Gelatin colonies rapidly liquefying, structureless.

A fairly well-defined type, appearing during the fall and winter of 1910–1911. Ten cultures studied.

Type 15 — Ps. 211.2333833

Rods .1–.3 by .5–.8 μ. Motility great. Flagella 3–6. No chains. Indol produced. Pellicle on broth (although one culture has no surface growth). Chromogenisis shows primarily in gelatin-stab cultures. Gelatin colonies rapidly liquefying, structureless.

Found only in one soil sample, October, 1909. Only three cultures studied.

Type 16 — Ps. $211.\overset{?}{2}3\overset{?}{3}\overset{?}{2}6\overset{?}{2}3$

Rods .2–.4 by .8–2 μ (a few with larger diameter). Motility slight. There seems to be one polar flagellum. Chains often produced. Indol varies. Growth in broth poor or none. Gelatin colonies liquefying, orange chromogenic, typically radiate in structure.

Variation in this type remarkably great. The cultures (twenty-three in all) are classed together because of two constant features — the orange to yellow chromogenisis, and the very long, thin rods. Since this type grows so very poorly in liquid media, it is thought possible that the variation may be due to the lack of satisfactory invigoration; preliminary cultivation was often accomplished on agar slants.

Very common, although never found in large numbers.

Type 17 — Ps. $221.23\overset{?}{2}\overset{?}{2}03\overset{?}{2}$

Rods .5–.8 by .8–2 μ (although one is smaller). Motility usually great, although one culture seems immotile. Flagella 1–3. No chains.

Indol not produced. No surface growth on broth. Gelatin colonies rapidly liquefying, structureless.

Not very constant, since there is great variation in acid production and nitrate reduction.

Isolated from only two samples, one in the fall of 1909 and the other in the fall of 1910. Five cultures studied.

Type 18 *Ps. fluorescens* (Flügge, 1886) Migula Ps. 211.2332133

Rods .3–.7 by .8–1.5 μ. Motility great. Flagella 1–3. No chains. Indol variable. No surface growth on broth. Gelatin colonies rapidly liquefying, structureless.

A fairly constant type, although the rate of liquefaction varies and fluorescence is not constant.

Fairly abundant at times, but found only in fall or winter in both years. Nine cultures studied.

Type 19 Ps. 211.2332023

Rods .3–.5 by .6–.8 μ. Motility great. Flagella 3–6. No chains. Indol negative. Slight ring, or no surface growth, on broth. Milk discolored, brown to green; a pungent odor produced. Gelatin colonies rapidly liquefying, structureless.

Isolated only once, in November, 1910. Three cultures studied.

Slow liquefiers; gelatin colonies punctiform

1. Flagella polar

Type 20 Ps. 211.3333033 (?)

Rods .4–.5 by .6–1.5 μ. Motility great. Flagella 3–6. No chains. Indol variable. No surface growth on broth.

Found only in the fall and early winter of 1910. Only three cultures studied, one of which differed from the others in having to be invigorated on agar.

2. Flagella absent

Type 21 Bact. 211.3333023

Rods .2–.5 by .3–.6 μ. No chains. Indol negative (except in one culture). No surface growth in broth.

Fairly constant. A moderately abundant type; seems to be characteristic of fall and early spring, but occurred to some extent in the winter of 1909–1910. Twelve cultures studied.

Type 22 Near *Bact. lactis citronis* Conn, 1906 Bact. 211.3333523

Rods .1–.3 by .3–.4 μ. No chains. Indol negative. No surface growth in broth.

Rather uncommon. Only three cultures. Found only in winter samples.

Type 25 Bact. $211.33330\overset{?}{2}3$

Rods .2–.4 by .4–.6 μ. No chains. Indol negative. No surface growth in broth. Characterized by the production of ammonia alone in nitrate broth.

Found abundantly in winter and in early spring, 1910; was again isolated in January, 1911. About twelve cultures studied; some of them could not be invigorated in broth at 30° C.

Type 26 Bact. 211.2332033

Large rods (over .8 μ in diameter). No chains. Indol probably negative, but not tested in every case. No surface growth on broth.

Type probably not distinct, size of rods varying greatly and one even seeming a micrococcus.

Not very abundant. Only five cultures studied. Found at various seasons.

Type 27 Bact. 211.3332023

Rods .2–.3 by .3–.5 μ. No chains. Indol positive.

One culture, however, has about twice this diameter; otherwise the agreement is good.

Found in the fall and winter of 1909–1910, and again in September, 1910. Only seven cultures studied.

Type 28 Bact. 211.3332023

Rods vary in size. They fall mostly into two groups, .4–.8 by .8–1.5 μ and .2–.4 by .5–1.5 μ, respectively. No chains. Indol negative. No surface growth in broth.

About ninety cultures studied. Some variation in size of the rods, as shown above; no sharp line can be drawn, however, therefore no subtypes are recognized. Otherwise the agreement on essential points is very good. There is some question as to how distinct the type is, since it is characterized almost wholly by negative features. Often could not be invigorated in broth at 30° C.

Very abundant. Has been isolated from practically every soil sample taken.

Type 29 Near *Bact. lactis citronis* Conn, 1906 Bact. 211.3332533

Rods .2–.4 by .8–1.5 μ. No chains. Indol variable. No surface growth in broth. Differs from type 22 chiefly in its failure to reduce nitrates.

Agreement very good except for indol production. One culture, however, is a very short rod, and another has a diameter twice as large as the others.

Not very abundant; seems characteristic of fall and winter. About twelve cultures studied.

Non-liquefiers; gelatin colonies punctiform

1. Flagella polar

Type 31 Ps. 212.2333033

Rods .4–.6 by .6–1.5 μ. Motility great. Flagella 2–3. No chains. Indol negative. No surface growth on broth.

Only two cultures studied, hence the type should perhaps not be regarded.

Type 32 Near *B. geminus* Ravenel Ps. 212.3333033

Rods .4–.6 by .8–2 μ. No chains. Indol negative (uncertain, since it was not always tested). No surface growth on broth.

Only four cultures studied.

Type 33 Ps. (?) 212.3332033

Rods .4–.7 by .6–1.5 μ. No chains. Motility usually great. Arrangement and number of flagella undetermined, but they are undoubtedly polar. Indol negative as far as determined. No surface growth in broth.

Type fairly distinct, but only six cultures were studied. Found at various seasons.

Type 34 Ps. (?) 212.3332033

Rods .8–1.4 by 1–4 μ. No chains. Apparently one flagellum, although two cultures seem immotile. Indol negative. No surface growth on broth. In some cases a depression formed in gelatin stab, but no real liquefaction.

Agreement good except for motility.

Found in the fall and winter of 1910–1911. Only five cultures studied.

2. Flagella absent

Type 35 Bact. 212.3332633

Rods .2–.5 by .6–1.2 μ. No chains. Indol negative. Slight surface growth, or none, in broth.

Apparently fairly distinct. It was necessary to invigorate two cultures at lower temperatures than 30° C., and in media containing dextrose.

Isolated only once, in February, 1910; then quite abundant. Three cultures studied.

Type 36 Bact. 212.3332034

Rods .2–.5 by .5–1.5 μ. Chains observed in one instance. Indol negative. As a rule no surface growth in broth; one culture, however, showing a ring.

Fairly distinct. Isolated at various seasons. Eight cultures studied.

Type 37 Bact. 212.2332033

Rods .3–.5 by .6–1.5 μ. No chains. Indol negative. No surface growth on broth.

Isolated only twice, in October, 1910, and January, 1911. Only three cultures studied.

Type 38 M. 212.2332033

Cocci .5–.8 μ. No chains. Indol negative. As a rule no surface growth in broth, but a ring in one case.

Seems fairly distinct, but only four cultures were studied. Isolated only in fall and spring.

Actinomyces—filamentous forms

Type 40 *Act. flavus*

Surface growth on agar leathery and somewhat glistening. May or may not be chromogenic. According to Sanfelice (1904) this type is partially acid-fast to the Ziehl-Gabbett stain.

This type is not claimed to be incapable of subdivision, or even absolutely distinct. It is one of the three types or groups recognized by Sanfelice. Further division is difficult.

This type is extremely abundant in the soil investigated and has been found in every sample. Only a few cultures, however, have been isolated and studied. With these the study has been difficult, since the methods employed with ordinary bacteria are not adapted to the Actinomyces. Hence even the few cultures isolated cannot be regarded as having been thoroughly studied.

Type 45 *Act. albus*

Surface growth on agar mildewy, owing to aërial hyphæ. Chromogenisis not infrequent, although less common than in the case of the *Act. flavus* type. Sanfelice (1904) claims that this type is not in the least acid-fast.

This is the second of Sanfelice's three types or groups, and, like *Act. flavus*, is not necessarily a species.

Not quite so common as the *Act. flavus* type, yet occurring, probably, in all the soil samples studied. As in the case of the other type, very few cultures were studied and those not thoroughly.

SUPPLEMENTARY TABLES

TABLE 16. WEATHER CONDITIONS ON DAYS OF SAMPLING

Date	When sampled			Preceding day			Second day before			Third day before			Date of last rain	Remarks
	Moisture content of soil (percentage)		Temperature of soil (degrees Fahrenheit)	Temperature (degrees Fahrenheit) of			Temperature (degrees Fahrenheit) of			Temperature (degrees Fahrenheit) of				
	Plat 4B	Plat 1B		Soil (4.30 p. m.)	Atmosphere Max.	Atmosphere Min.	Soil (4.30 p. m.)	Atmosphere Max.	Atmosphere Min.	Soil (4.30 p. m.)	Atmosphere Max.	Atmosphere Min.		
1909													1909	
Apr. 17	26.5	30.0	......	......	61	29	.....	48	29	......	39	33	Apr. 14	
May 25	18.4	17.2	......	......	70	39	.....	59	41	......	57	46	May 18	
July 16	16.5	16.4	......	......	90	60	......	88	55	......	86	63	July 3	Short storm on 15th, following very dry weather
Sept. 16	23.6	29.0	66	70	79	68	70	91	64	67	81	61	Sept. 10	Raining at time of sampling
Oct 8	19.4	20.8	51	......	72	39	......	70	36	57	66	36	Sept. 30	
Nov. 23	25.4	22.1	46	48	61	43	46	61	43	42	58	35	Nov. 22	Soil partly frozen on the 15th, but then thawed
1910													1910	
Jan. 21	62.1	41.8	33	......	43	17	......	33	30	33	46	32	....	Ground frozen, snow-covered
Feb. 7	45.3	......	34	......	12	—1	......	30	12	......	40	16	....	Ground frozen, snow-covered
Feb. 26	58.9	51.2	32?	......	22	—6	......	22	—6	......	19	14	....	Ground frozen, snow-covered
Mar. 25	21.2	18.3	46	......	79	44	......	60	33	......	62	41	Mar. 7	
Apr. 15	22.0	17.0	46	47	72	31	45	57	26	42	46	30	Apr. 11	After a very dry spring
May 28	28.0	29.0	54	55	52	45	......	65	45	60	62	52	May 27	
June 15	23.8	23.1	60	63	86	53	60	77	54	......	70	54	June 11	
July 2	17.2	16.6	......	71	93	62	71	85	57	70	85	56	June 16	
Aug. 20	16.6	15.4	......	72	76	46	69	72	58	72	75	63	Aug. 18	
Sept. 21	20.0	20.0	59	62	67	53	63	81	61	......	68	47	Sept. 13	
Oct. 12	23.2	20.2	54	55	72	44	52	54	42	55	58	48	Oct. 7	
Nov. 12	29.5	23.6	39	......	38	29	......	55	38	......	40	32	Nov. 9	
Nov. 30	30.0	25.0	37	36	36	32	......	39	23	36	36	23	Nov. 28	Ground snow-covered, but not frozen
Dec. 19	38.8	33.9	34	34	34	18	34	26	—1	34	13	—1	....	Ground snow-covered, partly frozen
1911													1911	
Jan. 4	40.0	41.6	32	33	30	17	33	50	38	33	41	20	Jan. 2	A thaw on January 2; plat 4B melted
Jan. 21	51.5	43.8	31	31	35	30	31	38	22	31	27	5	....	Ground frozen
Feb. 8	68.0	52.3	31	31	27	19	31	19	5	31	33	10	....	Ground frozen, snow-covered
Feb. 22	52.6	38.7	31	31	17	9	31	27	11	31	30	11	....	Ground frozen, snow-covered
Mar. 3	37.3	38.3	31	31	34	23	31	34	15	31	22	14	....	Ground frozen, snow-covered
Mar. 29	33.3	37.6	35	33	36	26	46	62	36	.....	56	38	Mar. 27	Surface slightly frozen
Apr. 12	28.5	21.9	40	......	36	34	48	55	28	......	52	29	Apr 9	

TABLE 17. TEMPERATURE AND RAINFALL, BY WEEKS

Week	Atmospheric temperature (average of daily means in degrees Fahrenheit)	Average soil temperature (degrees Fahrenheit)	Rainfall (inches)	Days of greatest rainfall and of thaws
1909				
March 28–April 3	38	......	0.31	March 30, April 2
April 4–10	44	......	0.28	April 9
April 11–17	44	......	1.49	April 13, 14
April 18–24	47	......	0.12	April 21
April 25–May 1	39	......	1.87	April 30, May 1
May 2–8	49	54	0.09	May 3
May 9–15	59	55	0.87	May 10, 14
May 16–22	57	54	0.04	May 18
May 23–29	57	57	0.38	May 27, 29
May 30–June 5	64	61	0.73	June 5
June 6–12	60	60	1.26	June 10
June 13–19	62	62	1.65	June 13, 17
June 20–26	76	70	0.35	June 22
June 27–July 3	71	66	0.05	July 3
July 4–10	64	65	0.00	
July 11–17	74	65?	0.26	July 16
July 18–24	65	65	1.18	July 24
July 25–31	74	69	0.11	July 29
August 1–7	70	71	0.00	
August 8–14	70	70	0.00	
August 15–21	63	65	1.25	August 15, 16, 19
August 22–28	69	69	0.31	August 26
August 29–September 4	61	60	0.09	August 29
September 5–11	60	......	1.13	September 10
September 12–18	66	69	0.50	September 16
September 19–25	60	......	1.06	September 23
September 26–October 2	53	......	0.25	September 30
October 3–9	55	55	0.00	
October 10–16	44	......	1.28	October 11
October 17–23	42	......	0.71	October 21, 23
October 24–30	40	......	0.11	October 24
October 31–November 6	49	......	0.16	November 4
November 7–13	43	......	0.12	November 8
November 14–20	44	45	0.12	November 17
November 21–27	38	......	0.63	November 25
November 28–December 4	36	......	0.05	November 28
December 5–11	29	......	0.09	December 7
December 12–18	29	......		
December 19–25	24	......		
December 26–January 1 (1910)	18	33		
1910				
January 2–8	20	33		
January 9–15	21	33		Ground snow-covered
January 16–22	30	33		
January 23–29	30	33		
January 30–February 5	26	32		
February 6–12	20	32		
February 13–19	23	32		
February 20–26	20	32		

TABLE 17 (*continued*)

Week	Atmospheric temperature (average of daily means in degrees Fahrenheit)	Average soil temperature (degrees Fahrenheit)	Rainfall (inches)	Days of greatest rainfall and of thaws
1910				
February 27–March 5	41	....	0.42	February 27, 28
March 6–12	35	....	0.17	March 6
March 13–19	32	45	0.04	March 14
March 20–26	45	....	0 02	March 20
March 27–April 2	55	50	0.00	
April 3–9	51	46	0.40	April 6, 7
April 10–16	47	45	0.30	April 11
April 17–23	52	49	1.41	April 19
April 24–30	50	47?	1.55	April 24, 29
May 1–7	52	49	0.87	May 3
May 8–14	49	50	0.41	May 9
May 15–21	57	56	0.66	May 20
May 22–28	59	56	1 92	May 24
May 29–June 4	52	54	0.36	June 1, 2, 3, 4
June 5–11	56	56	0 97	June 6, 11
June 12–18	66	65	0.15	June 16
June 19–25	66	66	0 00	
June 26–July 2	73	66	0.01	
July 3–9	73	70	0.03	July 7
July 10–16	75	69	1.28	July 12, 16
July 17–23	69	69	Tr.	
July 24–30	74	69	0.31	July 27, 29
July 31–August 6	67	69	0 21	August 1
August 7–13	66	68	0.89	August 10
August 14–20	69	70	0 44	August 18
August 21–27	70	68	0 55	August 26
August 28–September 3	65	65	1.00	September 3
September 4–10	67	65	0.70	September 6
September 11–17	59	60	0.17	September 13
September 18–24	61	61	0.36	September 24
September 25–October 1	62	60	2.41	September 25
October 2–8	57	59	1.21	October 6
October 9–15	52	53	Tr.	
October 16–22	56	55	0.23	October 22
October 23–29	44	47	1.08	October 25
October 30–November 5	40	44?	1.05	November 4
November 6–12	35	40?	0.46	November 9
November 13–19	33	37	0.16	November 19
November 20–26	36	37	0.39	November 25
November 27–December 3	29	36		Ground snow-covered
December 4–10	17	36		
December 11–17	18	34		
December 18–24	25	34		
December 25–31	24	33	0.25	Thaw December 28, 29
1911				
January 1–7	25	33	0.20	Soil thawed January 1, 2
January 8–14	32	33	0.84	Thaws January 8, 11, 13, 14

TABLE 17 (*concluded*)

Week	Atmospheric temperature (average of daily means in degrees Fahrenheit)	Average soil temperature (degrees Fahrenheit)	Rainfall (inches)	Days of greatest rainfall and of thaws
1911				
January 15–21	24	33	....	Ground snow-covered until January 20
January 22–28	34	33	0.26	Thaw January 25–27
January 29–February 4	26	32		Ground snow-covered
February 5–11	26	31		
February 12–18	32	31	1 46	
February 19–25	24	31		
February 26–March 4	28	31		
March 5–11	26	32		
March 12–18	29	32	0 27	March 12
March 19–25	30	38?	0.32	March 20
March 26–April 1	37	45?	0 92	March 26, 27
April 2–8	37	.....	0 71	

TABLE 18. COMPOSITION OF MEDIA

Liquid media

	Laboratory number	Peptone (percentage)	Sodium chlorid (percentage)	Miscellaneous substances (percentage)	Reaction to phenolphthalein
Bouillon	1.02	1.0	0.5	0.3 Liebig's beef extract.	0.5 per cent acid
Dunham's solution	1.30	1.0	0.5	....	Not adjusted
Nitrate broth	1.40	0.1	.....	0.2 potassium nitrate.....	Not adjusted
Dextrose broth	1.31	1.0	0.5	1.0 dextrose.	Neutral
Lactose broth	1.33	1 0	0.5	1.0 lactose..	Neutral
Sucrose broth	1.35	1.0	0.5	1.0 sucrose ..	Neutral
Glycerin broth	1.37	1.0	0.5	1.0 glycerin...	Neutral

Solid media

Containing 12 per cent gelatin

	Laboratory number	Peptone (percentage)	Sodium chlorid (percentage)	Dextrose (percentage)	Soil extract (percentage)	Miscellaneous substances (percentage)	Reaction to phenolphthalein
Standard	2.02	1.0	0.5	...	.....	0.3 Liebig's...	0.5 per cent acid
Soil extract	2.12	1.0	0.5	.....	20 0	0.3 Liebig's...	0.5 per cent acid
Ordinary	2.20	......	......	0.1	20.0	....	0.5 per cent acid
Ordinary	2.22	.....	......	0 1	20.0	0.1 ammonium tartrate....	0.5 per cent acid

TABLE 18 (*concluded*)

Containing 1.2 per cent agar

	Laboratory number	Peptone (percentage)	Potassium acid phosphate (percentage)	Dextrose (percentage)	Soil extract (percentage)	Miscellaneous substances (percentage)	Reaction to phenolphthalein
Ordinary .	3.12	1.000	.	. ...	20.0	0.30 Liebig's ..	0.5 per cent acid
Fischer's.. .	.	...	0.20	......	100.0 (sodium carbonate)..	. . .	Not adjusted
Lipman's	...	0.005	0.05	1.0	. .	0.02 magnesium sulfate.	Not adjusted

Of the above media, 2.20 gave the most satisfactory results in qualitative work and has been ordinarily employed; quantitatively Fischer's agar has given slightly higher results. None of the other media were used at all generally for plating; medium 3.12 was used merely for agar slants.

Soil extract for all except Fischer's agar was prepared as follows: A weighed quantity of soil was heated in an autoclave for one hour at a pressure of two atmospheres, then mixed with an equal weight of water and allowed to stand overnight. The soil was then boiled for thirty minutes and filtered. The total solids in this extract were determined and the extract was diluted, if necessary, to bring the solids to about .14 per cent. For Fischer's agar the soil was prepared differently, as follows: Soil was mixed with an equal weight of a .1-per-cent solution of crystalline Na_2CO_3, and heated in an autoclave for thirty minutes at a pressure of one atmosphere. This was then filtered, through a clay filter if necessary.

BIBLIOGRAPHY

American Public Health Association

1912 Standard methods for the examination of water and sewage. 2d ed., pp. 1–144.

Caron, A.

1895 Landwirtschaftlich-bakteriologische probleme. Landw. vers. stat. **45**:401–418.

Chester, F. D.

1903 Studies in soil bacteriology. Delaware Agr. Exp. Sta. Rept. **14**:46–78.

1904 The bacteriological analysis of soils. Delaware Agr. Exp. Sta. Bul. 65:49–76.

Clark, C. F.
1908 The environment of the plant, including a study of the crop-producing power of a so-called infertile soil. Thesis for degree of M. S. in Agr., Cornell University, 1908. (Unpublished.)

Conn, H. J.
1910a Future methods of soil bacteriological investigations. Centbl. bakt. 2: **25**:454–457.
1910b Bacteria in frozen soil. Centbl. bakt. 2:**28**:422–434.
1912 Bacteria of frozen soil. II. Centbl. bakt. 2:**32**:70–97.

Conn, H. W., and Esten, W. M.
1903 Qualitative analysis of bacteria in market milk. Connecticut (Storrs) Agr. Exp. Sta. Rept. **15**:63–91.

Conn, H. W., Esten, W. M., and Stocking, W. A.
1907 A classification of dairy bacteria. Connecticut (Storrs) Agr. Exp. Sta. Rept. **18**:91–203.

Dachnowski, Alfred
1909 Bog toxins and their effect upon soils. Bot. gaz. **47**:389–405.

Ehrenberg, Paul
1904 Die bakterielle bodenuntersuchung in ihrer bedeutung für die feststellung der bodenfruchtbarkeit. Landw. jahrb. **33**:1–139.

Engberding, Diedrich
1909 Vergleichende untersuchungen uber die bakterienzahl im ackerboden in ihrer abhängigkeit von äusseren einflüssen. Centbl. bakt. 2:**23**:569–642.

Fabricius, Otto, and Feilitzen, Hjalmar von
1905 Ueber den gehalt an bakterien in jungfräulichem und kultiviertem hochmoorboden auf dem versuchsfelde des Schwedischen moorkulturvereins bei Flahult. Centbl. bakt. 2:**14**:161–168.

Fischer, Hugo
1909a Über den einfluss des kalkes auf die bakterien eines bodens. Landw. vers. stat. **70**:335–342.
1909b Bakteriologisch-chemische untersuchungen. Bakteriologischer teil. (Bacteriological investigations on soil.) Landw. jahrb. **38**:355–364.
1909c Zur methode der bakteriologischen bodenuntersuchung. Centbl. bakt. 2:**22**:654–655.
1909d Besitzen wir eine brauchbare methode der bakteriologischen bodenuntersuchung? Centbl. bakt. 2:**23**:144–159.

1909e Über die physiologische wirkung von bodenauszügen. Centbl. bakt. 2:**24**:62–74.
1910 Zur methodik der bakterienzählung. Centbl. bakt. 2: **25**:457–459.

Fränkel, Carl
1887 Untersuchungen über das vorkommen von mikroorganismen in verschiedenen bodenschichten. Zeitsch. hygiene **2**:536.

Gottheil, O.
1901 Botanische beschreibung einiger bodenbakterien. Centbl. bakt. 2:**7**:430–435, 449–465, 481–497, 529–544, 582–591, 627–637, 680–691, 717–730.

Harding, H. A.
1910 The constancy of certain physiological characteristics in the classification of bacteria. New York (Geneva) Agr. Exp. Sta. Technical bul. 13:1–41.

Harding, H. A., and Prucha, M. J.
1908 The bacterial flora of cheddar cheese. New York (Geneva) Agr. Exp. Sta. Technical bul. 8:121–193.

Hiltner, L., and Störmer, K.
1903 Studien über die bakterienflora des ackerbodens, mit besonderer berücksichtigung ihres verhaltens nach einer behandlung mit schwefelkohlenstoff und nach brache. Kaiserliches Gesundheitsamt, Biol. Abt. Land-u. Forstw. Arb. **3**:445–545.

Hoffmann, Conrad
1906 Relation of soil bacteria to nitrogenous decomposition. Wisconsin Agr. Exp. Sta. Rept. **23**:120–134.

Koch, Alfred
1899 Untersuchungen über die ursachen der rebenmüdigkeit, mit besonderer berücksichtigung der schwefelkohlenstoff-behandlung. Deut. Landw. Gesell. Arb. **40**:1–44.

Krüger, W., and Heinze, B.
1907 Untersuchungen über das wesen der brache. Landw. jahrb. **36**:383–423.

Lipman, J. G., and Brown, P. E.
1908 Report of the Soil Chemist and Bacteriologist. New Jersey Agr. Exp. Sta. Rept. **28**:141–204.

Lipman, J. G., Brown, P. E., and Owen, J. L.
1909 Report of the Soil Chemist and Bacteriologist. New Jersey Agr. Exp. Sta. Rept. **29**:91–147.

Meyer, Arthur
1903 Practicum der botanischen bakterienkunde. Mikroskopisches practicum **2**:1–157.

Neide, Ernst
1904 Botanische beschreibung einiger sporenbildenden bakterien. Centbl. bakt. 2:**12**:1–32, 161–176, 337–352, 539–554.

Remy, Th.
1902 Bodenbakteriologische studien. Centbl. bakt. 2:**8**:657–662, 699–705, 728–735, 761–769.

Russell, E. J., and Hutchinson, H. B.
1909 Effect of partial sterilization of soil on the production of plant-food. Journ. agr. sci. **3**:111.
1913 The effect of partial sterilization of soil on the production of plant-food. Journ. agr. sci. **5**:152.

Sanfelice, Francesco
1904 Ueber die pathogene wirkung einiger Streptothrix-(Actinomyces-)arten. Centbl. bakt. 1 Orig.:**36**:355–367.

Squires, J. H.
1909 A study of some of the properties of a non-productive soil. Thesis for degree of Ph. D., Cornell University, 1909. (Unpublished.)

Stevens, F. L., Withers, W. A., et al.
1909a Nitrification in soils and in solutions. North Carolina Agr. Exp. Sta. Rept. **31**:40. Centbl. bakt. 2:**23**:355–373.
1909b Ammonification in soils and in solutions. Centbl. bakt. 2:**23**:776–785.

Wohltmann, F., Fischer, Hugo, and Schneider, Philipp
1904 Bodenbakteriologische und bodenchemische studien aus dem versuchsfelde. Journ. landw. **52**:97–126.

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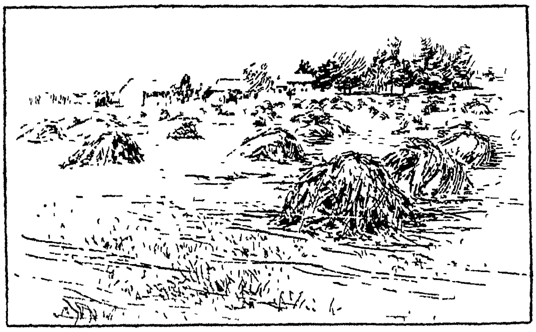
Department of Soil Technology

EXPERIMENTS CONCERNING THE TOP-DRESSING OF TIMOTHY AND ALFALFA

BY T. LYTTLETON LYON AND JAMES A. BIZZELL



Timothy meadow top-dressed in spring with 200 pounds nitrate of soda, 100 pounds acid phosphate, and 50 pounds muriate of potash

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EXPERIMENTS CONCERNING THE TOP-DRESSING OF TIMOTHY AND ALFALFA

T. LYTTLETON LYON AND JAMES A. BIZZELL

(Received for publication September 10, 1913)

TOP-DRESSING TIMOTHY, AND THE EFFECT OF THIS ON OTHER CROPS IN THE ROTATION

In 1903 was begun an experiment, the purpose of which was to ascertain the effect of certain fertilizer constituents, and of combinations of these constituents, on the yield of timothy when grown on the type of soil used in the experiment.* It was intended to keep timothy on the land for three years, following this with corn, oats, and wheat, respectively, during the succeeding three years, at the end of which time the land was again to be seeded to timothy. This plan has been followed and the second three-years period of timothy has expired. The present report, therefore, covers the results of the first rotation and one half of the second.

The soil

The soil on which the experiment is being conducted is described as the "silty phase of Dunkirk clay loam." It is very tenacious and difficult to work except when a favorable degree of moisture obtains. This type of soil is well adapted to the growth of timothy and small grain but not to that of corn. The tract is slightly rolling and fairly well drained. In 1902 the land was in corn; in 1903 a crop of oats was harvested from it.

The plats

The experiment comprises a series of twenty-two plats. They are of rectangular shape, 226.5 feet long by 19.25 feet wide, making an area of one tenth acre. The plats are separated one from another by a strip of ground 2 feet wide.

Crops grown

Timothy was to have been seeded in the fall of 1903, but wet weather prevented this. Seeding was accomplished in the spring of 1904, with oats as a nurse crop. During the seasons of 1905, 1906, and 1907 the plats were in timothy. In 1908 corn was grown, in 1909 oats, and in 1910 wheat. In 1911, 1912, and 1913 timothy was again grown.

* The experiment was planned by Professor T. F. Hunt. Reports have been made in bulletins of this station as follows: Bulletin 232, by Gilmore and Fraser; Bulletin 241, by Gilmore and Clark; Bulletin 261, by Bizzell and Morgan; Bulletin 273, by Lyon and Morgan.

Method of manurial treatment

The kinds of commercial fertilizers used are given in Table 1, as are also the rates of application of these and of farm manure. The fertilizers and the manure were applied to the timothy crops only, not to any of the grain crops. Commercial fertilizers were applied on the following dates: September 16, 1903; April 5, 1905; April 17, 1906; May 1, 1907; May 4, 1911; April 30, 1912; April 12, 1913. Farm manure was applied on September 16, 1903; October 2, 1906; April 25, 1911; November 1, 1912. At the close of 1913, therefore, there have been seven applications of commercial fertilizer and four of farm manure. The applications to each plat since the beginning of the experiment have been as designated in the table, with the following exceptions: in 1904 and 1905 plat 727 received at each application 160 pounds of nitrate of soda, instead of 320 pounds as in 1906, 1907, 1911, 1912, 1913; in 1911 and 1913 this plat received 160 pounds of muriate of potash instead of 80 pounds; in 1904 and 1905 plat 728 received 160 pounds of "niterlime," instead of 640 pounds of nitrate of soda as in 1906 and 1907.

Effect of fertilizers applied to timothy on the corn, oat, and wheat crops following it

After having been in timothy for three years the plats were plowed in the autumn of 1907, the sod being turned under to a depth of seven or eight inches. In the spring of 1908 the soil was prepared for corn with the disk and spring-tooth harrows. On May 29 all plats were planted to Pride of the North corn that had been grown for several years on the university farm. The hills were $3\frac{1}{2}$ feet apart each way. When the corn was four inches high it was thinned to four stalks to a hill. The corn was cultivated on June 8, June 23, July 7, and July 20. On September 24 the corn kernels had reached the glazed stage, and all plats were harvested.

In the autumn of 1908 the plats were plowed, and after being harrowed in the following spring they were drilled to American Banner oats on May 5. The oats made a good growth and were harvested on August 7.

In the autumn of 1909 the land was plowed and then drilled to Dawson's Golden Chaff wheat. This made a normal growth and was harvested on July 26.

The three grain crops having been grown without fertilization of the soil other than that given for the hay crops, it is interesting to see how the yields of the plats fertilized for the preceding hay crops compare with the plats having had no fertilizers applied to them. This is shown in tables 1 and 2.

In these tables is brought out the fact that fertilization of the soil for timothy increases its productiveness for succeeding crops. The greatest

TABLE I. YIELDS PER ACRE OF GRAIN CROPS NOT FERTILIZED BUT GROWN ON PLATS THAT WERE FERTILIZED FOR TIMOTHY

Plat	Treatment for timothy (quantities per acre)	Corn in 1908		Oats in 1909		Wheat in 1910	
		Grain (bushels)	Stover (pounds)	Grain (bushels)	Straw (pounds)	Grain (bushels)	Straw (pounds)
711	No fertilizer	29 3	2,184	24.1	1,111	24.1	1,895
712	320 pounds acid phosphate	32 6	2,436	34.4	1,198	23 5	1,528
713	80 pounds muriate of potash	47 1	2,592	33 3	1,271	21.0	2,261
714	No fertilizer	28.5	2,340	37 8	1,283	25.4	1,705
715	160 pounds nitrate of soda	34 3	2,220	40.3	1,384	21.1	1,605
716	160 pounds nitrate of soda; 320 pounds acid phosphate	37.7	2,364	37.5	1,377	20.7	1,550
717	No fertilizer	30.0	2,052	31.2	982	19.5	1,410
718	320 pounds acid phosphate; 80 pounds muriate of potash	54.0	2,628	35.1	1,214	17.2	1,150
719	160 pounds nitrate of soda; 80 pounds muriate of potash	47.0	2,244	36.8	1,274	18.3	1,410
720	No fertilizer	35.1	2,304	33.5	1,060	19.3	1,620
721	160 pounds nitrate of soda; 80 pounds muriate of potash; 320 pounds acid phosphate	55.7	2,880	36.4	1,171	18.7	1,390
722	160 pounds nitrate of soda; 80 pounds muriate of potash; 640 pounds acid phosphate	54 9	2,988	32.1	957	16.7	1,295
723	No fertilizer	26.2	2,040	25.7	863	18.5	1,440
724	320 pounds nitrate of soda; 80 pounds muriate of potash; 640 pounds acid phosphate	53.7	2,844	33.7	819	19.2	1,420
725	320 pounds nitrate of soda; 80 pounds muriate of potash; 320 pounds acid phosphate	62.9	3,108	38.2	1,102	19.5	1,540
726	No fertilizer	33.4	2,328	29.7	852	22.8	1,280
727	320 pounds nitrate of soda; 80 pounds muriate of potash; 320 pounds acid phosphate	57.8	2,844	35.8	1,282	19.0	1,390
728	640 pounds nitrate of soda; 80 pounds muriate of potash; 320 pounds acid phosphate	55.9	2,940	37.3	1,134	18.0	1,360
729	No fertilizer	29.3	2,340	27.1	897	16.2	1,210
730	No fertilizer	31.7	2,244	26 0	922	15.2	1,150
731	10 tons farm manure	66.7	3,024	35 4	1,522	19.8	1,410
732	20 tons farm manure	68.2	3,888	41.1	2,033	23.6	2,035

benefit was derived by the corn crop, which immediately followed the timothy. The oat crop, which followed corn, experienced the next greatest benefit, and the wheat crop, after oats, was the least benefited.

An interesting condition occurred in 1910, when a number of the previously fertilized plats yielded less than those that had not been fertilized at any time. It may be seen that this occurred on the less heavily fertilized plats. Apparently the fertilization stimulated the growth of the preceding crops to such an extent that they were able to secure a supply of mineral substances not available to the unfertilized plats. When the effect of the fertilization ceased the plants on these plats found the mineral nutrients less available.

The question naturally suggests itself, whether this stimulating effect of fertilizers produces a permanent injury and whether the continued use of fertilizers will require constantly increasing quantities in order to maintain crop yields at a given level. Possibly the best known answer to

TABLE 2. APPARENT INCREASE IN YIELDS PER ACRE ON PLATS FERTILIZED FOR TIMOTHY OVER UNFERTILIZED PLATS

Plat	Treatment for timothy (quantities per acre)	Corn in 1908		Oats in 1909		Wheat in 1910	
		Grain (bushels)	Stover (pounds)	Grain (bushels)	Straw (pounds)	Grain (bushels)	Straw (pounds)
711	No fertilizer	......	......	......	......	......	......
712	320 pounds acid phosphate	3 5	200	5.1	29	—1 0	—304
713	80 pounds muriate of potash	18 4	305	—0.2	45	—4.0	493
714	No fertilizer	......	......	......	......	......	......
715	160 pounds nitrate of soda	5 3	—24	4.6	201	—2.4	—2
716	160 pounds nitrate of soda 320 pounds acid phosphate	8.2	216	4.0	294	—0.8	42
717	No fertilizer	......	......	......	......	......	......
718	320 pounds acid phosphate 80 pounds muriate of potash	12 8	492	3 1	206	—2 3	—330
719	160 pounds nitrate of soda 80 pounds muriate of potash	13.5	—24	4.0	240	—1.0	—140
720	No fertilizer	......	......	......	......	......	......
721	160 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	23.6	665	5.6	177	—0.4	—170
722	160 pounds nitrate of soda 80 pounds muriate of potash 640 pounds acid phosphate	25.7	860	3.8	28	—2.0	—205
723	No fertilizer	......	......	......	......	......	......
724	320 pounds nitrate of soda 80 pounds muriate of potash 640 pounds acid phosphate	25.0	709	6.6	—41	0.9	33
725	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	31.9	877	9.8	246	1.5	207
726	No fertilizer	......	......	......	......	......	......
727	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	25.7	512	6.9	415	1.8	133
728	640 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	25.2	605	9.4	253	1.3	127
729	No fertilizer	......	......	......	......	......	......
730	No fertilizer	......	......	......	......	......	......
731	10 tons farm manure	35.0	780	9.4	600	4.7	260
732	20 tons farm manure	36.5	1,644	15.1	1,111	8.4	885

this question is to be obtained from some of the fertilized plats on the Broadbalk wheat field at the Rothamsted Experiment Station in England. For sixty years wheat has been raised continuously on these plats, and where a suitable combination has been used there has been no marked falling-off in the yields during the last forty years although some of the elements supplied in the fertilizers are not equal to the quantities removed by the crops and drainage.

It is the large quantities of nitrogen that have been instrumental in preventing the yields on the fertilized plats from falling below the yields on the unfertilized ones. Still more effective, in this respect, has been the farm manure. Even with these fertilizers, however, the yields, as compared with the unfertilized plats, constantly diminished, and in time would doubtless have fallen below the yields on the check plats.

In the years in which timothy was grown on these plats, applications of 640 pounds of acid phosphate per acre gave smaller yields of hay than did

applications of 320 pounds. With the large applications there was a very considerable residue of phosphorus left in the soil. This, with the heavy grass sod in a state of decay, might be expected to have caused a better yield of grain than on those plats to which smaller quantities of acid phosphate were added. This appears, however, not to have been the case. Comparing plat 721 with 722 and plat 724 with 725, it may be seen that the yields are almost uniformly higher on the plats that received the smaller application of acid phosphate. The larger quantity of acid phosphate was unproductive, not only for the crop to which it was added but also for the succeeding crops.

Residual effect of fertilizers and fertilizing value of timothy sod

The yields of the grain crops following the hay crops may give some information as to whether the fertilizers had a markedly residual effect, or whether the increased growth of timothy sod was chiefly instrumental in increasing the yields of grain on the fertilized plats. It will be remembered that only the timothy was fertilized and that the succeeding grain crops received no fertilization.

TABLE 3. PERCENTAGE INCREASE OF YIELDS ON FERTILIZED OVER UNFERTILIZED PLATS

Plat	Units of fertilizer elements applied			Hay average 1905–1907	Corn grain 1908	Oats grain 1909	Wheat grain 1910	Average of three grain crops
	Nitrogen	Potassium	Phosphorus					
712	0	0	1	21.7	12.2	17.4	—4.2	8.5
713	0	1	0	30.8	64.1	—0.7	—15.9	15.8
715	1	0	0	38.9	18.3	13 0	—10.1	7.1
716	1	0	1	53.5	27.9	12.1	—3.7	12.1
718	0	1	1	34.2	31.1	9.6	—11.7	9.7
719	1	1	0	69.8	40.5	12.4	—5.4	15.8
721	1	1	1	85.5	73.2	18.0	—2.0	29.7
722	1	1	2	71.8	87.9	13.5	—10.8	30.2
724	2	1	2	128.2	87.4	24.6	5.2	39.1
725	2	1	1	145.1	102.9	34.7	8.6	48.7
727	2	1	1	135.8	80.6	24.1	10.7	38 5
728	4	1	1	*184.5	82.1	33.5	8.0	41.2
731	10 tons farm manure......			154.6	110.4	36.0	30.8	59 1
732	20 tons farm manure......			264.6	115.3	58.0	55.5	76.3

* Average for 1906–1907.

An examination of Table 3 shows that the percentage increases of yield are always larger for the average of the three hay crops than for the three

grain crops, as is to be expected from the fact that the former were the crops to which the fertilizers were applied.

The applications of the single ingredients, phosphorus, potassium, and nitrogen, resulted in a larger increased yield of hay from nitrogen than from either of the other substances; but for the grain crops the average increase from this constituent was least, although phosphorus was almost as inactive.

Phosphorus appears to have little influence on the grain crops. Comparing plats 721 and 722, it will be noticed that the increased average yield of grain crops was nearly the same, although the application of acid phosphate was doubled on the latter plat. A comparison of plats 724 and 725 or 727 shows similar results. It is true that the double application of acid phosphate depressed the yields of hay in both cases, but it might be expected to be of benefit to succeeding crops.

The plats receiving the large applications of nitrate of soda in a complete fertilizer showed the greatest percentage increase of both hay and grain. It would thus appear that the timothy sod was of itself an important factor in the fertilization of the grain crops. In this capacity the timothy sod doubtless acts through the decay of its organic matter, thus liberating carbon dioxid and leaving in a readily available condition the mineral substances in its ash.

The farm manure shows a strong residual action, for, although plat 731 yielded less hay than did plat 728, it gave a much larger yield of grain.

Financial gain from use of fertilizers

In considering the financial gain from the use of fertilizers for these crops, it must be remembered that the hay crops only were fertilized and that the cost of the fertilizers is to be charged only against the hay crops. Therefore any increased yields of grain on the fertilized plats were pure gain. On the other hand, any decreases in yields of grain on the fertilized plats must be charged against the gains from the hay crops on the corresponding plats.

In making the calculations the cost of fertilizers was reckoned as follows: nitrate of soda, $56 per ton; muriate of potash, $46 per ton; acid phosphate, $14 per ton, except in 1913 when a phosphate containing 16 per cent of available phosphoric acid was used and the cost was placed at $16; farm manure, $1.50 per ton. The values of the crops were reckoned as follows: timothy hay, $12 per ton; corn, 66 cents per bushel; oats, 43 cents per bushel; wheat, 90 cents per bushel. These were approximately the average farm prices in New York State for the years 1900 to 1909, as compiled for the Yearbook of the United States Department of Agriculture for 1911. Stover was considered to be worth $3 and straw $5 per ton, which is probably not far from the average farm price.

On this basis it is of interest to ascertain what the gain from the use of fertilizers will be for the entire rotation when different quantities of fertilizer constituents are used and when farm manure is applied. Of course the values of products and of fertilizer material vary in different localities and the results are not of universal application. But results of fertilizer experiments never are of universal application, since they vary with different soils. They are suggestive rather than final, but they may nevertheless be of much value as a guide to profitable fertilizer practice. The price of farm manure doubtless varies more than does that of any other of the materials employed. The prices used represent the probable cost of manure that is purchased and hauled for a few miles. Manure produced and used on the same farm would doubtless cost less.

In Table 4 are shown the gains from the use of the different fertilizer applications for one rotation, after deducting the cost of the material and when no other charges are made.

The total gain from the use of fertilizers for the rotation does not, of course, represent the net profit to the farmer, nor does it contain all the charges that should be considered in comparing the relative profitableness of the fertilizers. It is difficult to place even an approximate value on the charges that should still be made. They consist in part of such items as cost of handling and spreading the material, interest on money invested, the added expense of harvesting and storing the crops, and other possibly less important items.

The gain or loss resulting from a certain fertilizer treatment may be reckoned on the basis of the land treated or on that of the fertilizer used. The fertilizer treatment that gives the greatest financial gain on an acre of land may not bring the greatest return for the money invested in the fertilizer. For instance, the treatment in this experiment that gave the greatest net gain for the six years was the farm manure applied to plat 732, while the treatment that resulted in the greatest return for the money invested in fertilizer was 80 pounds of muriate of potash on plat 713. The figures are as follows:

Plat	Treatment	Net gain from crops	Net gain from each dollar invested in fertilizer
713	80 pounds muriate of potash....................	$22.56	$4.09
732	20 tons farm manure...	78.70	1.31

Both these methods of calculating returns are of value in determining the profit of a fertilizer treatment, but in either case the ability of the

TABLE 4. GAIN PER ACRE FROM THE USE OF FERTILIZER APPLICATIONS FOR ONE ROTATION, AFTER DEDUCTING COST OF MATERIAL

Plat	Treatment for timothy (quantities per acre)	Net gain from hay			Net gain from grain crops			Net gain from six crops	Cost of fertilizer for six crops	Net gain from each dollar invested in fertilizer
		1905	1906	1907	Corn	Oats	Wheat			
712	320 pounds acid phosphate	$ 1.40	$ 0.26	$ 3.90	$ 2.61	$2.24	—$1.68	$ 8.73	$ 6.72	$1.30
713	80 pounds muriate of potash	3.88	5.50	2.88	12.60	0.04	—2.34	22.56	5.52	4.09
715	160 pounds nitrate of soda	2.82	5.89	—0.30	3.46	2.47	—2.14	12.20	13.44	0.91
716	160 pounds nitrate of soda 320 pounds acid phosphate	2.72	6.04	0.14	5.73	2.46	—0.63	16.46	20.16	0 82
718	320 pounds acid phosphate 80 pounds muriate of potash	—1.12	6.50	1.50	9.19	1.82	—2.87	15.02	12.54	1.20
719	160 pounds nitrate of soda 80 pounds muriate of potash	5.08	8.50	4.94	8.87	2.32	—1.30	28.41	18.96	1.50
721	160 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	2.90	9.56	11.45	16.58	2.80	—0.78	42.51	25.08	1.69
722	160 pounds nitrate of soda 80 pounds muriate of potash 640 pounds acid phosphate	—2.44	3.02	6.31	18.25	1.70	—2.34	24.50	32.40	0.76
724	320 pounds nitrate of soda 80 pounds muriate of potash 640 pounds acid phosphate	3.01	12.85	8.85	17.56	2.92	1.48	46.67	45.75	1.02
725	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	11.78	12.14	12.32	22.37	4.83	1.92	65.36	39.12	1.67
727	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	......	11.68	12.80	17.73	2.98	1.98	....	....	....
728	640 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	......	6.70	10.38	17.54	4.62	1.52	....	....	....
731	10 tons farm manure	0.57	11.64	11.34	24.27	5.49	4.85	58.16	30.00	1.94
732	20 tons farm manure	—5.85	30.06	8.94	26.56	9.20	9.79	78.70	60 00	1.31

treatment to maintain soil fertility must be reckoned in the final decision. On consulting Table 8 it becomes quite evident that muriate of potash alone on plat 713 failed to keep up the fertility of the soil in the second rotation of timothy, while farm manure on plat 732 did do so.

Certain treatments stand out with sufficient prominence to show their

TABLE 5. YIELDS OF TIMOTHY HAY FOR EACH YEAR OF THE FIRST AND OF THE SECOND CYCLE OF THE ROTATION

Plat	Fertilizer used (quantities per acre)	Yields of hay per acre (in pounds)							
		1905	1906	1907	Average for three years	1911	1912	1913	Average for three years
711	No fertilizer	1,910	4,360	4,530	3,600	2,380	2,640	3,290	2,770
712	320 pounds acid phosphate	2,680	4,670	5,350	4,233	2,340	2,630	4,460	3,143
713	80 pounds muriate of potash	3,190	5,370	4,910	4,490	2,540	3,190	3,640	3,123
714	No fertilizer	2,400	4,040	3,920	3,453	2,660	3,080	3,310	3,017
715	160 pounds nitrate of soda	3,550	5,590	4,450	4,530	3,880	4,930	5,340	4,717
716	160 pounds nitrate of soda 320 pounds acid phosphate	3,840	5,820	4,730	4,797	4,020	4,870	4,440	4,443
717	No fertilizer	2,200	3,520	3,120	2,947	2,300	2,280	2,870	2,483
718	320 pounds acid phosphate 80 pounds muriate of potash	2,800	5,360	4,220	4,127	2,530	3,040	4,610	3,393
719	160 pounds nitrate of soda 80 pounds muriate of potash	4,280	6,110	4,990	5,127	3,760	4,940	5,230	4,643
720	No fertilizer	2,470	3,700	2,980	3,050	2,160	2,370	2,410	2,313
721	160 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	4,590	6,550	5,960	5,700	4,050	5,280	5,580	4,970
722	160 pounds nitrate of soda 80 pounds muriate of potash 640 pounds acid phosphate	4,350	5,730	5,730	5,270	3,820	5,350	5,570	4,913
723	No fertilizer	3,200	3,290	2,830	3,107	1,760	2,160	1,810	1,910
724	320 pounds nitrate of soda 80 pounds muriate of potash 640 pounds acid phosphate	5,880	7,940	6,950	6,923	4,600	6,180	7,640	6,140
725	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	6,610	7,420	7,280	7,103	4,290	6,460	7,470	6,073
726	No fertilizer	2,110	3,190	3,140	2,813	2,060	1,990	1,680	1,910
*727	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	4,310	7,110	7,250	6,223	4,660	6,480	8,010	6,383
728	640 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	2,470	7,590	8,160	6,073	4,850	6,040	7,800	6,230
729	No fertilizer	1,570	2,590	2,550	2,237	1,780	2,080	1,700	1,853
730	No fertilizer	1,420	2,230	2,350	2,000	2,040	2,070	1,880	1,997
731	10 tons farm manure	4,090	4,350	6,840	5,093	2,980	5,610	6,560	5,050
732	20 tons farm manure	5,520	7,420	8,940	7,293	4,490	8,150	8,530	7,057
	Average of plats 731 and 732	4,805	5,885	7,890	6,193	3,735	6,880	7,545	6,053

* Potassium was doubled in 1911 and in 1913.

profitableness or unprofitableness even should the unmeasured items be of considerable size. For instance, the use of 320 pounds of nitrate of soda was more profitable than the use of half that quantity; the application of 640 pounds of acid phosphate was in each of the two cases attended by a marked decrease in financial gain; a complete fertilizer, when well balanced, was better than the application of only one or two constituents.

The experiment shows that fairly large quantities of fertilizer may be applied to timothy on this soil to advantage. It also brings out the fact

that the corn crop, when immediately following the timothy, benefited greatly from the fertilizer treatment; and that when 20 tons of manure was twice applied to timothy the three grain crops that followed it received substantial benefit.

The data accumulated at the end of the first half of the second rotation would, it was hoped, give some information on two questions — whether there is a tendency for the yields on the fertilized plats to decrease, and whether the use of the fertilizers on hay continues to be profitable.

The yields of hay on all the plats for each year of the first and of the second cycle of the rotations are shown in Table 5.

It is evident that the yields for the second three years are not so large as those for the first three years. Whether this is due to poorer seasons, to deterioration of the soil, or to a combination of the two conditions, it is difficult to say. Only by continuing the experiments over a very long period can this be accurately determined. A comparison of the yields on the unfertilized plats with the yields on the plats receiving complete fertilizers may give some information on this subject. These yields are given in Table 6 and are shown graphically in Fig. 13.

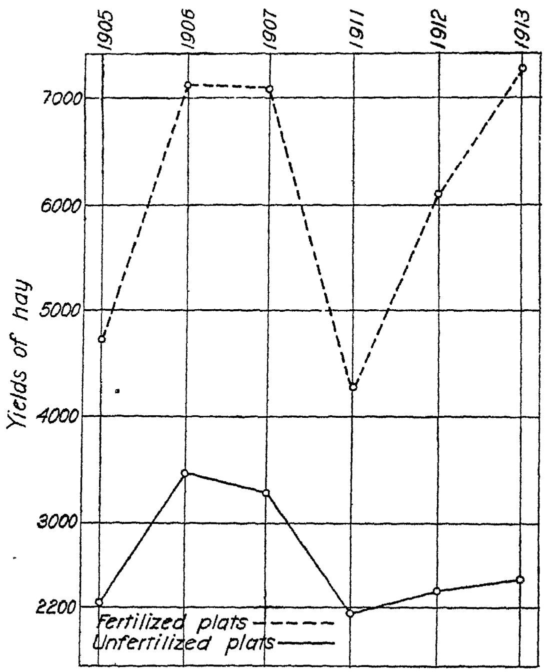

FIG. 13.— *Average yields of timothy hay (in pounds per acre) on the unfertilized plats and on the plats receiving complete fertilizer, for each year in the first and in the second cycle of the rotation*

TABLE 6. AVERAGE YIELDS ON UNFERTILIZED PLATS AND ON PLATS RECEIVING COMPLETE FERTILIZER MIXTURES

Plats averaged	1905	1906	1907	Average for three years	1911	1912	1913	Average for three years
Unfertilized plats* 711, 714, 717, 720, 723, 726, 730...	2,244	3,476	3,267	2,996	2,194	2,370	2,464	2,343
Fertilized plats 722, 724, 725, 727, 728...	4,724	7,158	7,074	6,506	4,444	6,102	7,298	5,948

* Not including plat 729.

The figures and the diagram show that both the unfertilized and the fertilized plats yielded less in the second rotation than in the first. The yields of the fertilized plats show relatively less falling-off than do the yields of the unfertilized plats; indeed, the yield of the fertilized plats in 1913 was greater than it was in any year of the first rotation. There would seem to be no reason to believe that the yields cannot be maintained by the use of fertilizers. The farm-manured plats, on the other hand, did not yield so well in any year of the second rotation as they did in the third year of the first rotation.

The apparent increase in yield resulting from the applications of various fertilizer constituents is shown in Table 7:

TABLE 7. APPARENT PERCENTAGE INCREASE IN YIELDS OF HAY DUE TO APPLICATIONS OF VARIOUS FERTILIZER CONSTITUENTS

	1905	1906	1907	Average for three years	1911	1912	1913	Average for three years
Nitrogen	52 6	41 5	19.5	38 9	52.7	75 2	68.8	65 6
Phosphorus	29.2	12 8	23 6	21.9	—5 4	—5 6	35.3	8 1
Potassium	43 5	29 5	19 5	30 8	—1 0	8 7	10 2	6 0
Nitrogen and phosphorus	69.4	57 4	33 7	53 5	66 1	91 2	47.2	68 2
Nitrogen and potassium	79 9	67.8	61.8	69 8	70 3	111 1	104 0	95 1
Phosphorus and potassium	22 3	49.7	30 7	34 2	12.2	31 6	69 7	37 8
Nitrogen, phosphorus, potassium	69 2	83.8	103 5	85.5	99.8	129 6	152.5	127.3
Nitrogen, phosphorus doubled, potassium	47.1	69.2	99.1	71.8	101 7	139.9	177.1	139 6
Nitrogen doubled, phosphorus doubled, potassium	107.3	143.7	133.5	128.2	147.3	193.7	335.8	225.6
Nitrogen doubled, phosphorus, potassium	165.6	130.0	139.8	145.1	118.9	215.4	333.4	222 6
Nitrogen doubled, phosphorus, potassium*	123 3	137.8	146.2	135 8	126.9	222 4	363.0	237.4
Nitrogen quadrupled, phosphorus, potassium	...	172 1	197 0	....	136 9	197 5	338 2	224.2

* Potassium was doubled in 1911 and in 1913.

The importance of nitrogen in the fertilizer for timothy is brought out more strikingly in the second three-years period than in the first except where it was used in quadruple quantities, on which plats the yields in the last three-years period were approximately the same as on the plats receiving only half the quantity.

Potassium, in the quantities used, was more effective than was phosphorus. Not only was the combination of nitrogen and potassium more potent as a grass-producer than was nitrogen and phosphorus, but doubling the quantity of potassium in the complete fertilizer caused a substantial increase in yield.

In the first three-years period, doubling the phosphorus in the complete fertilizer caused in each of the two cases a decrease in yield. The reverse

TABLE 8. NET GAINS PER ACRE FROM USE OF FERTILIZERS FOR EACH YEAR THAT HAY WAS GROWN, AND AVERAGES FOR THE HAY CROPS IN THE FIRST AND IN THE SECOND ROTATION

Plat	Fertilizer used (quantities per acre)	Net gain from use of fertilizers			Total for three years	Net gain from use of fertilizers			Total for three years	Cost of fertilizer for six crops of hay	Net gain from each dollar invested in fertilizer
		1905	1906	1907		1911	1912	1913			
712	320 pounds acid phosphate	$ 1.40	$ 0.26	$ 3 90	$ 5 56	—$3 04	—$3.14	$ 4 42	—$1.76	$ 13.76	$0.28
713	80 pounds muriate of potash	3.88	5 50	2.88	12.26	—2.00	—0 30	0 37	—1.93	11.04	0 94
715	160 pounds nitrate of soda	2 82	5.89	—0.30	8.41	3 56	8.22	8.58	20.36	26.88	1.07
716	160 pounds nitrate of soda 320 pounds acid phosphate	2.72	6.04	0.14	8.90	2 88	7.18	1.50	11 56	40.64	0 50
718	320 pounds acid phosphate 80 pounds muriate of potash	—1.12	6.50	1.50	6.88	—2 52	0.20	6 96	4.64	25.50	0 45
719	160 pounds nitrate of soda 80 pounds muriate of potash	5.08	8.50	4.94	18.52	2.99	9.28	9.68	21.95	37.92	1.07
721	160 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	2.90	9.56	11.45	23.91	3.51	9.25	11.34	24.10	50.68	0.95
722	160 pounds nitrate of soda 80 pounds muriate of potash 640 pounds acid phosphate	—2.44	3.02	6.31	6.89	0.76	7.92	9 92	18 60	65.44	0.39
724	320 pounds nitrate of soda 80 pounds muriate of potash 640 pounds acid phosphate	3.01	12 85	8.85	24.71	—2.05	9.22	11.50	18 67	92.17	0 47
725	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	11.78	12.14	12.32	36.24	0.94	14.08	21.12	36.14	78.56	0.92
*727	320 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	......	11.68	12.80	......	0.75	13.78	22.48	37.01	......	....
728	640 pounds nitrate of soda 80 pounds muriate of potash 320 pounds acid phosphate	......	6.70	10.38	......	—5.30	1.96	11.80	8.46	......	....
731	10 tons farm manure	0.57	11.64	11.34	23 55	—9.37	21.24	11 22	23.09	60.00	0 78
732	20 tons farm manure	—5.85	30.06	8.94	33 15	—15 30	36 48	9 96	31.14	120.00	0.54

* Potassium was doubled in 1911 and in 1913.

was true in the second three-years period. Possibly the three unfertilized grain crops had caused a heavy drain on the soil supply of phosphorus.

Results with fertilizers in second three-years period stated in terms of money.— The unfertilized plats were less productive in the second three-years hay period than in the first. The fertilized plats were also less productive, but the falling-off in the yields on the fertilized plats was not so great relatively as on the unfertilized. The net gain from the use of fertilizers was about the same for the second as for the first period in hay.

The net financial gains for each year in hay, and the averages for the first and second periods, are given in Table 8.

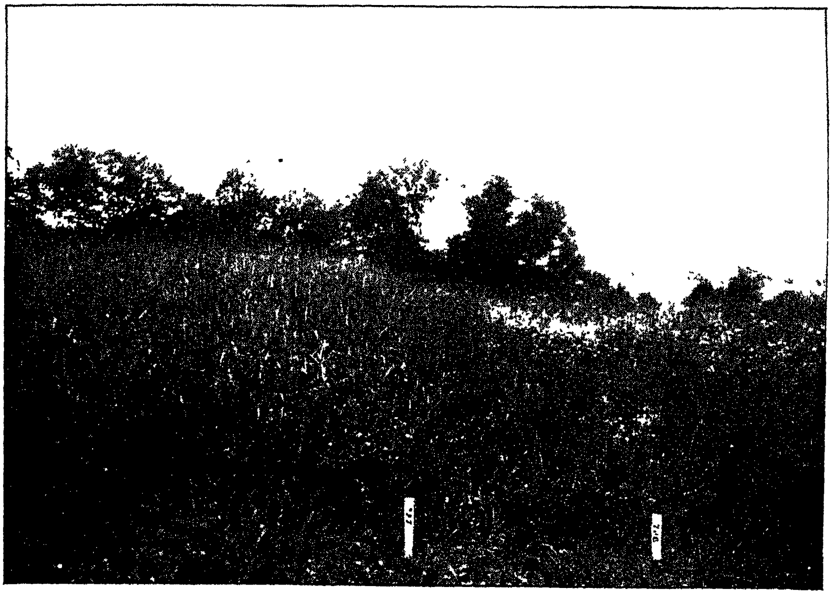

FIG. 14.— *Growth of timothy on unfertilized plat (726), and on plat (727) top-dressed with fertilizer at the rate per acre of 320 pounds nitrate of soda, 160 pounds muriate of potash, 320 pounds acid phosphate*

The net gains from the use of fertilizers in the second rotation agree fairly well with those in the first. The most profitable combination used was 320 pounds nitrate of soda, 160 pounds muriate of potash, and 320 pounds of acid phosphate. These are not the largest quantities of nitrate of soda and of acid phosphate used in the experiments. Where double the quantities of these constituents were used they were unprofitable. In the case of muriate of potash used in a complete fertilizer, 160 pounds gave a very slight financial gain over 80 pounds; if all expenses had been included, the greater quantity would possibly not have shown a profit.

The use of a quantity intermediate between 80 pounds and 160 pounds of muriate of potash would doubtless have increased the gain.

The acid phosphate was probably at about the maximum for its profitable use when used at the rate of 320 pounds per acre, since the double quantity failed to produce any material increase in yield and resulted in a positive decrease in monetary gain.

Nitrate of soda would probably have reduced the net gain if used in quantities much larger than 320 pounds per acre, since double that quantity produced a very decided falling-off in net gain.

FIG. 15.— *Growth of timothy on unfertilized plat (729), and on plat (728) top-dressed with fertilizer at the rate per acre of 640 pounds nitrate of soda, 80 pounds muriate of potash, 320 pounds acid phosphate. Note the daisies and other weeds on the unfertilized plat*

The most difficult fertilizer on which to place a value for the purpose of calculating financial gain is farm manure. In the bulletins in which these experiments have previously been discussed, the cost of farm manure was taken at 50 cents per ton. The price of farm manure when bought and hauled would probably be nearer $1.50 per ton, and, although the change is a radical one, it has been made in the financial calculations here presented. On this basis the net gain from farm manure was less than from the most profitable combination of fertilizers.

In the bulletin containing the results of the three crops of hay grown

in the first rotation,* a fertilizer mixture composed of 200 pounds nitrate of soda, 100 pounds acid phosphate, and 50 pounds muriate of potash per acre was recommended as an annual top-dressing for timothy. The results of the second three years of timothy in the experiment appear to justify the recommendation. If any deviation from this formula is indicated, it is a small increase in the quantity of potash.

In considering the financial gains it is of course necessary to take into account the entire rotation. It was shown in Table 4 that when the grain crops, as well as the hay, were included, the most profitable form of fertilizer was farm manure. It is evident, therefore, than when farm manure is available it is the best material to use. A good combination of commercial fertilizer, however, when used in a rotation like the one followed in this experiment, may give nearly as good results as does farm manure.

The hay crop furnishes an admirable opportunity to convert mineral fertilizer into organic matter, which may be used as a substitute for manure. On most farms there will always be a deficient supply of farm manure. The use of commercial fertilizers on the hay crop may so increase the growth of sod as to add a very considerable quantity of organic matter to the soil when the sod is plowed under. The farm manure may then be used for other crops.

EXPERIMENTS IN TOP-DRESSING ALFALFA

In the spring of 1906 an area of a little more than one acre of land on the university farm was seeded to alfalfa. The soil on which the seeding was done consisted of a clay loam of the type known as Dunkirk clay loam. It is a heavy, compact soil with a still more compact subsoil. One reason for seeding this area was in order to ascertain whether alfalfa would thrive on so heavy a soil. The land was accordingly prepared with great care and every precaution was taken to obtain a good stand. The result was a very uniformly distributed stand of alfalfa, which for several years yielded three cuttings of hay regularly each year. The annual cut for the period 1907 to 1910 inclusive amounted to about 4.5 tons per acre. As the hay showed signs of deterioration by 1910, it was decided, at the suggestion of Professor J. L. Stone, to try some experiments in top-dressing the soil.

Method of treatment

The first experiment was not begun until after the first crop had been cut in 1911. After the hay was removed the area was laid off into nine plats; each plat was 33 feet by 132 feet, or one tenth acre, in size. There were spaces 2 feet wide between plats, but these spaces contained alfalfa

* Bizzell, J. A., and Morgan, J. O. Third report on the influence of manures on the yield of timothy hay. Cornell Univ. Agr. Exp. Sta. Bul. 261.

which was cut and removed before each crop was harvested from the plats. The first applications of fertilizer were made on June 16. The plat treatments are shown in Table 9:

TABLE 9 TREATMENT OF ALFALFA PLATS

Plats	Fertilizer applied (quantities per acre)	Dates of application
5001, 5005, 5009	None	
5002, 5006 . . .	5 tons farm manure.	June 16, 1911
5003, 5007.	100 pounds acid phosphate. . . .	June 16, 1911, April 24, 1912
5004, 5008 . . .	100 pounds acid phosphate. . ; 16 pounds muriate of potash	June 16, 1911, April 24, 1912

A period of very dry weather followed the applications of the fertilizers, and, since it was apparent that not enough of the material had penetrated the soil to affect the yield of the second cutting, no weighings were made of that crop. The third cutting in 1911 was therefore the first cutting weighed.

In 1912 no application of farm manure was made, since the original dressing of that material was relatively much greater and more expensive than the fertilizer applications. On April 24 the other plats received the same dressings of acid phosphate and of muriate of potash as they had before. No other application was made during that year. The alfalfa was cut on June 28, August 2, and September 28.

The increased yields of the fertilized plats due to the fertilizer treatment have been calculated from the yields on the unfertilized plats, and are stated in Table 10 and shown graphically in Fig. 16.

TABLE 10. APPARENT INCREASE IN YIELDS DUE TO FERTILIZER TREATMENTS

Plats	Fertilizer applied (quantities per acre)	Number of applications	Increase in yields of hay per acre at each cutting (in pounds)				Total increase in yields of hay (pounds)
			Sept. 23 1911	June 28 1912	Aug. 2 1912	Sept. 28 1912	
5002, 5006. .	5 tons farm manure. . . .	1	310	225	140	125	800
5003, 5007. .	100 pounds acid phosphate.	2	225	405	40	—15	655
5004, 5008. .	100 pounds acid phosphate. . . . . ; 16 pounds muriate of potash.	2	235	315	105	40	695

Farm manure apparently produced the best results, the total yields of the four crops of hay being greatest on the plats receiving that fertilizer. There was not a great difference between the plats receiving acid phosphate alone and those receiving acid phosphate and muriate of potash, although the latter gave somewhat higher yields.

FIG. 16.—*Showing average increase per acre in 1911 and 1912 of top-dressed alfalfa plats over unfertilized plats. From left to right: acid phosphate and muriate of potash, acid phosphate alone, farm manure*

Commercial fertilizer apparently produced a marked response to each treatment, and it is a question whether it would not have been profitable to apply the dressing for each cutting, thus giving three applications each year. This was done in 1913; but during the previous winter the alfalfa plants had nearly all been killed, and, since the crop harvested was largely grass and weeds, the experiment does not apply to alfalfa.

Financial returns from fertilizer applications

In computing the financial results of the experimental treatments, farm manure is considered to be worth $1.50 per ton, acid phosphate $14 per ton (containing 14 per cent of available phosphoric acid), and muriate of potash $45 per ton. The value of the alfalfa is reckoned at $12 per ton. The application of these values and the apparent financial gain from the treatments are given in Table 11:

TABLE 11. FINANCIAL STATEMENT OF CERTAIN FACTORS IN THE EXPERIMENT

Plats	Fertilizer applied (quantities per acre)	Number of applications	Value of increased yields of hay per acre	Cost of all applications of fertilizer per acre	Net gain or loss from use of fertilizer on one acre
5002, 5006	5 tons farm manure. . . .	1	$4.80	$7.50	—$2.70
5003, 5007	100 pounds acid phosphate	2	3.93	1.40	2.53
5004, 5008	100 pounds acid phosphate. 16 pounds muriate of potash	2	4.17	2.12	2.05

The greatest net gain appears to have been derived from the use of acid phosphate alone. The high cost of the farm manure made its use

result in loss, in spite of the fact that the value of the increased yields of hay on the plats to which it was applied was greater than that produced by any other treatment. If the experiment could have been continued longer, as was originally intended, there is no doubt that the farm manure would have made a more favorable showing. It is not likely, however, that it would have proved more profitable than the use of acid phosphate, since even for the third cutting the application of phosphate responded in a good gain, which could have been repeated for each cutting. If, on the other hand, the alfalfa crop had been plowed up and some other crop planted on the land, the residual value of the farm manure would doubtless have been considerable.

The experiment demonstrates that acid phosphate in quantities of 100 pounds per acre can profitably be used for top-dressing alfalfa, after the alfalfa has been seeded for five or six years on land treated in this way.

A COMPARISON OF THE INFLUENCE OF ALFALFA AND OF TIMOTHY ON SUCCEEDING CROPS

In the spring of 1906 contiguous plats of land on Caldwell Field were sown to alfalfa and timothy, respectively. At the time when the seeding was done, a part of each plat received an application of quicklime at the rate of 2000 pounds per acre. The part of each plat not limed was given a dressing of nitrate of soda at the rate of 200 pounds per acre at the time of seeding, but thereafter no commercial fertilizer nor manure was added at any time.

In the spring of 1910 strips of land 10 feet wide through both the limed and the unlimed sections of both the alfalfa and the timothy plats were hoed bare of vegetation, and were kept free from plants of all kinds during 1910 and 1911. In the spring of 1912 the alfalfa and the timothy were plowed under on the entire area and the plats were planted to corn. This was followed by oats in 1913. The yields of both the grain crops are recorded as a measure of the effect of the alfalfa and the timothy on the productivity of the soil. These are stated in Table 12:

TABLE 12. YIELDS OF CORN AND OATS ON LAND PREVIOUSLY PLANTED TO ALFALFA AND TO TIMOTHY

Plat	Previous crop	Yield of corn per acre		Yield of oats per acre	
		Grain (bushels)	Stover (pounds)	Grain (bushels)	Straw (pounds)
4001	Alfalfa	62	7,075	26	1,575
4002	Timothy	47	5,875	27	1,450

The growth of corn was notably greater on the alfalfa soil than on the timothy soil. While no records of these plats before they were planted to the hay crops are available, and no check plats were used, it is probably safe to infer that their difference in productiveness was due in large measure to the influence of the previous crop.

The nitrogen content of the alfalfa soil and of the timothy soil

No analyses of the soils of these plats had been made before the alfalfa and the timothy were seeded, but samples were taken in the autumn of 1911 and again in the autumn of 1912 and the nitrogen content was determined. The data do not permit of an accurate estimate of the quantity of nitrogen accumulated or lost by the soil during the period in which the crops grew, because it cannot be assumed that at the beginning of the experiment the soil of the two plats contained about the same quantity of nitrogen although they were contiguous.

In 1911 samples of soil for analysis were taken from each of the planted sections of the plats and from the bare strip in each section. Nine borings to a depth of eight inches were made in each section. This gave one boring for each twenty-seven square feet of land. In 1912 borings were made to the same depth, one to every sixteen square feet. The average percentage of nitrogen for the two analyses of each of the sections of the plats is given in Table 13:

TABLE 13. PERCENTAGE OF NITROGEN IN SOIL OF PLATS PLANTED TO ALFALFA AND TO TIMOTHY FROM 1906 TO 1911 INCLUSIVE

Plat	Section 1		Section 2	
	Alfalfa 4001 a	Timothy 4002 a	Alfalfa 4001 c	Timothy 4002 c
North end (planted)	0.134	0 135	0.145	0.138
Middle (bare)	0.123	0 121	0 139	0.126
South end (planted)	0.144	0.135	0.149	0.131
Average	0 134	0 130	0.144	0.132

The differences in the nitrogen content of the alfalfa and timothy soils is hardly large enough and consistent enough to be significant when all the possibilities of error are considered. It may be concluded, however, that the alfalfa soil does not contain less nitrogen than does the timothy soil, but not to exceed .01 per cent more. The annual removal of nitrogen in

the alfalfa hay was much greater than that removed in the timothy hay. Nitrogen was determined in the alfalfa and the timothy from the limed and the unlimed soil. Yields of the hay from these plats were estimated by weighing several, but not all, of the crops. From these figures it is estimated that the alfalfa removed 208 pounds of nitrogen annually, and the timothy 62 pounds. That being the case, there must have been a large fixation of atmospheric nitrogen by the alfalfa crop to supply this removal without depleting the store of soil nitrogen below that in the timothy soil.

On the other hand, the nitrogen balance in the two plats at the end of the six years was not greatly different. The average difference was not more than .01 per cent. A difference of .01 per cent in the nitrogen content of the soil to a depth of eight inches would represent about 250 pounds of nitrogen per acre if an acre of soil to that depth weighed 2,500,000 pounds.

The quantity of nitrogen contained in the corn crop from the alfalfa plat was 88 pounds. The corn crop from the timothy plat contained 69 pounds of nitrogen. Thus there was evidently a more readily available supply of nitrogen in the alfalfa soil than in the timothy soil throughout the growing season, as is indicated also by analyses of the corn crop at different periods. These are given in Table 14:

TABLE 14 PERCENTAGE OF NITROGEN IN DRY MATTER OF CORN GROWN ON LAND PREVIOUSLY PLANTED TO ALFALFA AND TO TIMOTHY

Plat	Previous crop	Percentage of nitrogen in dry matter of corn			
		July 18	August 2	October 7	
				Grain	Stover
4001	Alfalfa	3.68	2.97	1.98	1.44
4002	Timothy	3.38	2.86	2.05	1.41

The figures show that the immature crop on the alfalfa soil contained a higher percentage of nitrogen than did that on the timothy soil. The mature crop showed no significant difference.

It has been shown previously by the writers that nitrate formation proceeds more rapidly in the alfalfa soil than in the timothy soil of these plats.* The difference in the total nitrogen content of the soil on the plats has been shown to be slight, and it is a question whether this differ-

* Lyon, T. L., and Bizzell, J. A. The influence of alfalfa and of timothy on the production of nitrates in soils. Centbl. bakt. 2:37:161-167.

ence is sufficient to account for the difference in quantity of nitrogen in the crops. It seems possible that it is the more ready availability of the nitrogen in the alfalfa soil, rather than its larger quantity, that has caused this soil to be more productive than the timothy soil.

It will be noticed in Table 13 that the nitrogen content of the strip that was kept free of all vegetation in 1910 and 1911 is lower than that of the parts of the plats on which either alfalfa or timothy was grown during these two years. This difference would be due in part to the greater nitrogen loss in the drainage water from bare soil than from planted soil. To offset this, however, there is the nitrogen removed in the alfalfa and the timothy of the cropped sections of the plats. In Table 15 is given a statement of the average nitrogen content of the planted and the bare soil on these plats:

TABLE 15. PERCENTAGE OF NITROGEN OF THE SOIL ON THE PLANTED AND ON THE BARE SECTIONS OF THE ALFALFA AND THE TIMOTHY PLATS

Plat	Section 1		Section 2	
	Alfalfa 4001 a	Timothy 4002 a	Alfalfa 4001 c	Timothy 4002 c
Planted section	0.139	0.135	0.147	0.134
Bare section	0.123	0.121	0.139	0.126
Difference	0.016	0.014	0.008	0.008

It will be seen in Table 15 that the nitrogen content of the bare sections of the alfalfa plat and of the bare sections of the timothy plat differ by about the same amount from the nitrogen content of the planted sections of those plats. This, together with the rather slight difference in the nitrogen content of the soil planted to the two crops, raises the interesting question whether the accumulation of nitrogen by the soil has been any greater under the alfalfa than it has been under the timothy. It seems possible that the large quantities of this element removed by the alfalfa crops, with the well-known propensity of that crop to use soil nitrates even when inoculated with nitrogen-fixing bacteria, may have been nearly sufficient to balance the greater accession of atmospheric nitrogen by the alfalfa soil.

THE USE OF MUCK AS A MEDIUM FOR THE TRANSPORTATION OF BACTERIA FOR ALFALFA INOCULATION

It was thought that muck might furnish a convenient medium in which to transport bacteria for the inoculation of soil for alfalfa or other legumes.

The advantages that muck apparently possesses are: (1) cheapness; (2) great hygroscopicity, which insures a moist medium; (3) freedom from weed seeds when taken from a considerable depth below the surface of the ground; (4) lightness, thus reducing the cost of shipping and possibly permitting the soil to be sown from the drill with the seed.

Muck soil was passed through a coarse screen in order to remove large lumps. It was then weighed, and five per cent of its weight in ground limestone was mixed with it. The muck had been kept in a pile in the greenhouse and was dry enough to pass readily through the screen.

Nodules from growing alfalfa plants were procured. About 10 grams of nodules were crushed in distilled water in a mortar and the infusion was made up to about 5 liters, which was used for inoculating the muck. The infusion thus added brought the moisture content to about 85 per cent of the dry weight of the material. It was allowed to stand in a pail for one week after being inoculated. After standing for a week a quantity of the muck was dried in the dark until it had no cohesion. Both the moist and the dry muck was used for inoculating the soil, the intention being to ascertain whether air-dry muck is a suitable medium for transporting the inoculation. As the hygroscopicity of muck is high, this material still held a large quantity of moisture.

The culture used on the seed was also obtained from the nodules of alfalfa plants. It was first grown on a medium composed of agar and nutrient salts with no nitrogen.

After it had been demonstrated that this culture was capable of producing nodules on the roots of alfalfa plants grown in the greenhouse, 100 cubic centimeters of distilled water and 1 gram of cane sugar was added to it and it was mixed with the alfalfa seed, which was spread out to dry in the laboratory and sown the next day. All these cultures were made and the muck was prepared by J. K. Wilson.

For the experiment, plats 3001 to 3011 on Caldwell Field were used. The plats were manured at the rate of five tons of horse manure per acre, which was plowed under in May. The land was then kept free from weeds by occasional harrowing until the latter part of June, when the plats were seeded. The treatment of the plats is shown in Table 16. The plats are each one one-hundredth acre in size. So far as could be ascertained, alfalfa had never been grown on this piece of land. Plats 3001 to 3006 were seeded on June 21, 1912, and plats 3007 to 3011 on June 29, 1912.

The soil used for inoculation was from a part of the field on which alfalfa had been growing for five years and in which the alfalfa roots were well supplied with nodules. Several successful inoculations had been made with this soil.

TABLE 16. TREATMENT OF PLATS IN ORDER TO TEST THE USE OF MUCK AS A MEDIUM FOR INOCULATING SOILS WITH THE BACTERIA-PRODUCING NODULES ON ROOTS OF ALFALFA

Plat	Treatment
3001	No inoculation
3002	Soil from old alfalfa field spread at rate of 200 pounds per acre
3003	Inoculated muck, dried, 30 pounds per acre
3004	Inoculated muck, moist, 30 pounds per acre
3005	Inoculated seed
3006	No inoculation
3007	Soil from old alfalfa field spread at rate of 200 pounds per acre
3008	Inoculated muck, dried, 30 pounds per acre
3009	Inoculated muck, moist, 30 pounds per acre
3010	Inoculated seed
3011	No inoculation

Alfalfa seed was sown broadcast at the rate of 30 pounds per acre. The soil was then treated with inoculating media as shown in Table 16, after which the land was harrowed to cover both seed and inoculating media. The same harrow was used on all plats in the following order: (1) plats not inoculated; (2) plats inoculated with dry muck; (3) plats inoculated with moist muck; (4) plats inoculated with culture on seed; (5) plats inoculated with alfalfa soil.

A good stand of alfalfa was obtained on all the plats. The weather was very dry until the latter part of July, when there was a heavy rain, and the weather continued cool and generally moist for the remainder of the summer. The first cutting was obtained on October 2. There was no appreciable loss by winterkilling during the succeeding winter, and growth started vigorously in the spring. There was a spot of land including parts of plats 3009, 3008, and 3007 on which the growth was better than on the surrounding soil, although there was no known reason why this should be so. The effect of this was the most marked in the order of the plats as given above, and doubtless was a disturbing factor in the results of the experiment. It was not very apparent the first year. The other plats had an apparently uniform growth throughout their entire areas.

In 1913 cuttings were made on June 26 and on August 1. The yields of cured hay at each cutting are given in Table 17.

All the inoculated plats yielded better than did the uninoculated plats, and the plats inoculated by means of muck gave larger crops than did those inoculated with alfalfa soil or with cultures on the seed. This difference, however, would probably not be great, and it may have been accidental or may have been due to the fertilizing properties of the muck It would appear that moist muck is a suitable medium for the growth of

Bacillus radicicola, the germ that forms nodules on the roots of alfalfa plants, and that this material may be air-dried and successfully used for the inoculation of soil on which alfalfa is to be planted.

TABLE 17. YIELDS OF ALFALFA HAY AT EACH CUTTING

Plat	Inoculating medium	Pounds of hay per acre			
		October 2 1912	June 26 1913	August 1 1913	Total
3001	None...	1,300	1,700	600	3,600
3002	Alfalfa soil.	2,200	2,100	900	5,200
3003	Dry muck	2,100	2,800	1,000	5,900
3004	Moist muck....	2,400	2,300	800	5,500
3005	Seed....	2,000	2,400	800	5,200
3006	None.	2,300	2,100	700	5,100
3007	Alfalfa soil	1,800	2,500	1,000	5,300
3008	Dry muck	2,200	2,800	1,900	6,900
3009	Moist muck	2,100	3,600	1,800	7,500
3010	Seed	2,000	3,000	1,200	6,200
3011	None....	1,300	1,800	400	3,500

SUMMARY

A series of field plats were subjected to a cropping rotation of timothy three years, corn, oats, and wheat each one year. Fertilizers or farm manure were applied to the timothy but not to any of the grain crops, different applications being used on different plats. The experiment has been conducted for nine years.

The results show that fertilization of the soil for timothy increases its productiveness for succeeding crops. The greatest benefit was derived by the corn crop, which immediately followed the timothy. The oat crop experienced the next greatest benefit, and the wheat the least.

Tabulations of the financial gains demonstrate that the use of fairly large applications of fertilizers was profitable, resulting in as much as $65 per acre net gain for the six years and giving a return of $1.67 for every dollar invested in the fertilizer.

Commercial fertilizers, while not superior to farm manure, were about equally effective. On grain crops commercial fertilizers are usually of less value than farm manure judiciously applied. This experiment indicates, therefore, that it is good practice to apply commercial fertilizers to timothy and thus save the farm manure for other crops.

Alfalfa that had been growing for six years was laid off in plats, which were top-dressed with (1) farm manure, (2) acid phosphate, (3) acid phos-

phate and muriate of potash. All these treatments caused an increase in the yields of hay. Farm manure produced a financial loss; the other treatments resulted in monetary gains, acid phosphate applied singly being superior in this respect.

Adjoining plats of land, on one of which alfalfa grew for six years and on the other of which timothy grew for the same length of time, were plowed, and were planted in one year to corn and in the next year to oats. The corn crop was considerably larger on the alfalfa land, the oats were equally good on the two plats.

Analyses of the soils from the two plats showed that the alfalfa soil contained not to exceed .01 per cent more nitrogen than did the timothy soil. When the soils were incubated, formation of nitrates proceeded more rapidly in the alfalfa soil than in the timothy soil.

These data raise, but are not sufficiently exhaustive to answer, two questions: (1) whether there was a greater accumulation of nitrogen in the alfalfa soil during the six years than there was in the timothy soil during the same period; (2) whether the greater productivity of the alfalfa soil was not due to the more ready availability of the nitrogen in the alfalfa soil rather than to its greater quantity.

Plats of land that were to be sown to alfalfa were inoculated with (1) soil from an old alfalfa field, (2) a culture of *Bacillus radicicola* in moist muck, (3) the same preparation air-dried, (4) a culture of the same bacillus on the seed. Yields of three crops were obtained from which it appears that moist muck is a suitable medium for the growth of *Bacillus radicicola* (the germ that forms nodules on the roots of alfalfa plants), and that this material may be air-dried and successfully used for the inoculation of soil on which alfalfa is to be planted.

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229 An apple orchard survey of Orleans county
260 American varieties of beans
272 Fire blight of pears, apples, quinces, etc.
273 The effect of fertilizers applied to timothy on the corn crop following it
283 The control of insect pests and plant diseases
286 The snow-white linden moth
289 Lime-sulfur as a summer spray
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328 Hop mildew
329 The fire blight disease in nursery stock
332 Oriental pears and their hybrids
333 Control of two elm-tree pests
334 A study of some factors influencing the yield and the moisture content of cheddar cheese
335 Scab disease of apples
336 Distribution of moisture and salt in butter
337 The Babcock test, with special reference to testing cream.

CIRCULARS

1 Testing the germination of seed corn
3 Some essentials in cheese-making
8 The elm leaf-beetle
9 Orange hawkweed or paint brush
12 The chemical analysis of soil
14 Working plans of Cornell poultry houses
15 Legume inoculation
16 The improved New York State gasoline-heated colony-house brooding system
17 The formation of cow-testing associations
18 Milking machines: their sterilization and their efficiency in producing clean milk
19 Late blight and rot of potatoes
20 The fire blight disease and its control in nursery stock
(Extension Circular No 1) A plan for a rural community center

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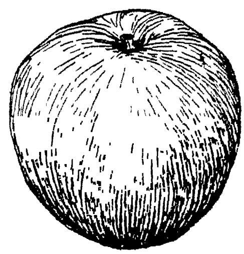
AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Plant Pathology

EXPERIMENTS IN THE DUSTING AND SPRAYING OF APPLES



By F M BLODGETT
Fellow in Plant Pathology

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CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION

Experimenting Staff

The regular bulletins of the Station are sent free to persons residing in New York State who request them.

Ithaca, New York, November 28, 1913.

ACTING DIRECTOR W. A. STOCKING, *College of Agriculture, Ithaca, New York:*

Dear Sir: I beg to submit herewith a report of work done under the Herman Frasch Industrial Fellowship, with the recommendation that it be published as Experiment Station Bulletin 340.

The work has been performed by F. M. Blodgett, Fellow, and represents investigations extending through the years 1911, 1912, and 1913. In 1911 the work was done in the orchard of William Smith, Albion, New York; in 1912 in the orchard of Lee Kinne, Hartwick Seminary, New York; and in 1913 in the orchards of E. W. Catchpole & Sons, North Rose, New York, and H. T. Lawson, Owego, New York. Special acknowledgment is due these men for their hearty cooperation in placing their orchards at our disposal and in liberally aiding the investigations in every possible way.

Valuable assistance in various technical details of the experiments has been rendered by Professors Crosby and Herrick, of the Department of Entomology at this University, Dr. T. J. Headlee of the New Jersey Agricultural Experiment Station, F. H. Pough of the Union Sulphur Company, New York City, and R. G. Harris, formerly with the Vreeland Chemical Company, New Brunswick, New Jersey. The materials used in 1913 were kindly furnished by the Union Sulphur Company and the Vreeland Chemical Company, and the dusting machines by the Kansas City Dust Sprayer Manufacturing Company.

Respectfully submitted,

DONALD REDDICK,
Professor of Plant Pathology.

CONTENTS

EXPERIMENTS IN THE DUSTING AND SPRAYING OF APPLES

F. M. Blodgett

(*Received for publication November 29, 1913*)

INTRODUCTORY

Apple-growers in New York are confronted constantly with new problems or with the recurrence of old problems. Not the least of these, either in number or in severity, are the diseases and the pests that ravage orchards. In fact, there are many growers who regard the control of pests and diseases as the limiting factor in the successful production of apples. Constant vigilance and repeated spraying must be practiced every year if first-class fruit is to be obtained. Wallace (1911) records a case — which at least two thousand New York fruit-growers saw for themselves — in which a block of trees in an orchard, generally conceded to receive as good care and as intelligent and careful treatment as any in the State, was left unsprayed for a single season, with the result that at picking time ninety-eight per cent of the fruit was scabby.

Orchardists very generally recognize the fact that the apple-scab disease is epidemic in nature, and that in epidemic years they are not nearly always successful in controlling it. Some of the essential factors in the successful control of orchard diseases were outlined by Reddick (1913) in an address before the New York State Fruit Growers' Association at Rochester in January, 1913. The most important factor emphasized in that address, and one that has received altogether too little attention, is the time element. The interrelation of bud development with the development of the scab fungus, and the relation of these to meteorological conditions — particularly the occurrence of rainfall — is set forth; and it is shown that for Baldwins and Rhode Island Greenings throughout western New York, the actual time limit in which effective spraying for scab could be done was on two occasions — the blossom cluster spray and the calyx spray — both in 1911 and in 1912, confined to four days. In the same address it is stated that very few men are in a position to spray their orchards thoroughly in so short a time. In general it may be said that New York apple-growers are awakening to the fact that they may make all the applications of spray usually recommended for the orchard

(1911) Wallace, Errett. Lime-sulfur as a summer spray. Cornell Univ. Agr. Exp. Sta. Bul. 289:142.

(1913) Reddick, Donald. Factors influencing successful orchard spraying. New York State Fruit Growers' Assoc. Rept. **1913**:51–54.

and still have scabby fruit Many growers appreciate that their spraying equipment is insufficient, and would be glad to supplement it if there were any assurance that they could have enough men and teams to operate additional equipment

The realization by growers of their inability to fight diseases and insects in epidemic years, and the knowledge of the fact that this is due in the main to their inability because of physical limitations to make applications of spray at the proper time, has awakened much interest in the popular accounts of dusting which have appeared from time to time in the agricultural press. The extraordinary claims made for the dry method certainly appeal strongly to the grower who appreciates the importance of applications of preventives at critical times.

It is claimed for the dust method that the time of application is not limited by conditions of soil, inasmuch as the lightness of the outfit permits its transportation in the orchard at all times; that trees in rough or hilly ground, or in localities remote from a satisfactory water supply, may be protected without unusual difficulty; that the expense is less than for liquid spraying, since the handling of a large bulk of water is eliminated, the trees are covered more rapidly, the outfit is less expensive, and the operators are fewer in number. The claim for the dust method which has appealed most strongly to the writer is the fact that such large areas may be covered in a short time; some operators have claimed to be able to dust thirty to fifty acres of orchard per day. The cost of preparing the dust mixture has not always received consideration; but, even should it be considerably more expensive than the liquid, the great saving in time and the ability to cover large areas at critical periods in a minimum of time would largely offset the added cost of the dust.

In spite of the claims made by enthusiasts from time to time for the dusting of orchards, the results of carefully planned experiments by members of experiment stations have never proved favorable for this method.

HISTORICAL

Some experimenters — Walker (1906), Close (1905, 1906), Farrand (1905) — succeeded in controlling the codling moth as well, or nearly as

(1905) Close, C. P. Dust spraying in Delaware. Delaware Agr. Exp. Sta. Bul. 69:1–7.

(1905) Farrand, T. A. Report of South Haven Sub-station for 1904. Michigan Agr. Exp. Sta. Spec. bul. 30:474–475.

(1906) Walker, Ernest. Suggestions upon the care of apple orchards. Arkansas Agr. Exp. Sta. Bul. 91:166–168, 205–206.

(1906) Close, C. P. Dust and liquid spraying. Delaware Agr. Exp. Sta. Bul. 72:1–22.

(1906) Close, C. P. Third report on dust and liquid spraying. Delaware Agr. Exp. Sta. Bul. 76:1–19.

well, with the dust as with liquid sprays. Crandall (1906), Blair (1907), and Pickett (1908) give reports of the work done in Illinois, which was principally on the control of scab and bitter rot

Crandall (1906) has presented the summary of conclusions reached as a result of the three-years experiments carried out in Illinois in the following words:

" Trees sprayed with liquid bordeaux and paris green retained their foliage in healthy working condition throughout the season. Dust-sprayed and check trees may be placed together because the behavior of foliage was the same in both. Leaves began falling in July and, in early September, these trees were practically denuded. This loss of foliage by dust-sprayed and check trees was due to apple scab, against which disease the dust spray was entirely ineffective.

" Differences in fruit were as marked as were differences in foliage. Liquid-sprayed trees give smooth fruit of good size. Dust-sprayed and check trees gave small ill-formed fruit, badly marked by scab and of very little value even as evaporator stock.

" Dust-spray is 52 per cent cheaper than liquid spray and it is easier to transport about the orchard. It has no other advantage.

" The results of the experiments are sufficiently decisive to warrant the conclusion that dust-spray is absolutely ineffective as a preventive of injury from prevailing orchard fungi, and that it is considerably less efficient as an insect remedy than is the liquid method of applying arsenites."

Among others who have carried out experiments is Faurot (1908), who reports experiments in Missouri resulting in four to five per cent scab-free fruit obtained by dusting with dry bordeaux as compared with ninety per cent obtained by spraying with liquid bordeaux. Lawrence (1906), in Washington, had equally poor results. Garman (1908) cites work in Oregon almost equally decisive. Craig (1904) sums up as follows some cooperative work carried out under his direction in New York State: " The labor and expense of applying dust sprays appear to be less than for sprays in liquid form. Six applications of dust spray were practically

(1904) Craig, John. The dust spray. Cornell Univ. Agr. Exp. Sta. Bul. 216:111–119.

(1906) Crandall, Charles S. Spraying apples. Relative merits of liquid and dust applications. Illinois Agr. Exp. Sta. Bul. 106:207–242.

(1906) Lawrence, W. H. Apple scab in eastern Washington. Washington Agr. Exp. Sta. Bul. 75:1–14.

(1907) Blair, Joseph C. Bitter rot of apples. Illinois Agr. Exp. Sta. Bul. 117:529.

(1907) Blair, J. C. Fruit and orchard investigations. Illinois Agr. Exp. Sta. Circ. 107:40–45.

(1908) Pickett, B. S. Spraying apple orchards for insects and fungi. Illinois Agr. Exp. Sta. Circ. 120:15–16.

(1908) Faurot, F. W. Spraying versus dusting. Missouri Fruit Sta. Bul. 19:1–24.

(1908) Garman, H. Apple orchard pests in Kentucky. Kentucky Agr. Exp. Sta. Bul. 133:66, 70–71.

not more effective on apples than two applications of bordeaux mixture; neither did they cost more." In these experiments the apples were graded as firsts, seconds, thirds, and so on, with no definite data on the control of apple scab.

Materials used in the above experiments

In all these experiments some form of the so-called "dry bordeaux" was used. In some of the experiments, the commercial preparation sold by the Dust Sprayer Manufacturing Company, of Kansas City, Missouri, was used, and in others a mixture was made up for the work. One of the commoner home-prepared mixtures is described by Waite (1906) as being composed of copper sulfate 4 pounds, quicklime 4 pounds, air-slaked lime 60 pounds. In other cases sal soda, caustic soda, and various other ingredients were included; but in all cases the essential fungicidal ingredient was some form of copper and the insecticidal agent was the well-known paris green. The extensive experiments performed seem to leave little doubt that a dry mixture containing copper as the fungicide is ineffective against our most important apple disease, scab, although dry paris green has in some instances proved effective against the chief insect enemy, codling moth.

CONSIDERATIONS LEADING TO INCEPTION OF THE PRESENT WORK

With the advent of lime-sulfur solution as an effective fungicide for the control of apple scab, the question arose as to what is the active agent in this case. Suggestions were first made as to what the active insecticidal agent is. Haywood (1907) writes: "From the decomposition of the wash there are obtained sulphur in a very finely divided form, thiosulphate for a time, and sulphite which is gradually set free. The writer is of the opinion that these are the active agents in killing insects." Haywood also gives the following decomposition products for lime-sulfur wash as determined by spraying filter papers and making analyses at stated intervals, in some cases spraying the papers with water in order to simulate dew:

TABLE 1. COMPOSITION OF DRY LIME-SULFUR-SALT WASH AFTER STANDING (EXPRESSED IN GRAMS PER 100 CUBIC CENTIMETERS OF SOLUTION)

Samples not watered					
Time of standing	Free sulfur	Sulfur as thiosulfates	Sulfur as sulfites	Sulfur as sulfates	Total sulfur
5 days	1.71	1.97	0.11	0.01	3 80
5 days	1.72	1.97	0.10	0.01	3 80
8 days	1.74	1.94	0.14	0.01	3 83
8 days	1.77	1.94	0.12	0.02	3.85

(1906) Waite, M. B. Fungicides and their use in preventing diseases of fruits. U. S. Agr. Dept. Farmers' bul. 243:11.

(1907) Haywood, J. K. The lime-sulphur-salt wash and its substitutes. U. S. Chem. Bur. Bul. 101:21.

TABLE I *(continued)*

Samples watered in order to simulate dew					
Time of standing	Free sulfur	Sulfur as thiosulfates	Sulfur as sulfites	Sulfur as sulfates	Total sulfur
10 days	1 94	1 66	0 22	.	3 82
10 days	1 93	1 69	0 20	..	3 82
4 weeks	2 11	1 42	0 29	0 15	3.97
4 weeks	2 13	1 41	0 27	0 16	3 97

From this table it may be seen that a considerable proportion of the lime-sulfur applied soon became free sulfur, and that the longer it remained on the filter papers, these being watered so as to simulate dew, the more sulfur was set free.

Similarly there has been question as to just which of these substances may be active fungicidal agents. Van Slyke and others (1910) made the following statement. "What specific compounds are directly responsible for the effects produced we are not yet certain. It is held, as the result of some experimental work, that the effect of the lime-sulphur mixture is not due to the direct action of calcium pentasulphide (CaS_5) or of calcium tetrasulphide (CaS_4), but is due rather to compounds that are formed from these, either calcium thiosulphate (CaS_2O_3), or free sulphur, or both." Wallace and others (1911) found that the sulfite and sulfate of calcium showed little fungicidal value. In the bulletin cited (page 181), results of using lime-sulfur solution precipitated with carbon dioxid are reported. The action of carbon dioxid on lime-sulfur solution alone would undoubtedly yield principally free sulfur and some hydrogen sulfid which, by the time the spray mixture was dried on the slides, would disappear or break down to form additional free sulfur. The fact, then, that this precipitated sulfur mixed with calcium carbonate had nearly as much fungicidal value as the original solution sprayed on the slides would seem to indicate that the fine sulfur had considerable fungicidal value. Apple and peach trees sprayed with this precipitated lime-sulfur bore out the laboratory observations on its effectiveness as a fungicide. It should be remembered, however, that sulfur deposited on the leaf from the drying of lime-sulfur solution, or that thrown down as a precipitate by carbon dioxid, is in a very fine state of division.

Aside from the known value of sulfur in the control of surface mildews, it has also been used in a mechanical mixture known as Scott's self-boiled

(1910) Van Slyke, L. L., Bosworth, A. W., and Hedges, C. C. Chemical investigation of best conditions for making the lime-sulphur wash. New York (Geneva) Agr. Exp. Sta. Bul. 329:432.

(1911) Wallace, E., Blodgett, F. M., and Hesler, L. R. Studies of the fungicidal value of lime-sulfur preparations. Cornell Univ. Agr. Exp. Sta. Bul. 290:192–193.

lime-sulfur which is principally a suspension of lime and sulfur. This is reported by Scott and Quaintance (1911) as giving uniformly good results on peaches for the control of brown rot and scab. It has been fairly effective on apples for the control of scab, but not so effective as lime-sulfur solution.

It is to be noted that, although considerably more sulfur is present in this spray than in lime-sulfur solution, the sulfur is not nearly so finely divided, especially when commercial flour is used. It was therefore thought worth while to test a very finely ground flour sulfur for the control of apple scab, both as a liquid spray and as a dry application. From the experience of the writer (1913) with mixtures of lime and sulfur in the control of hop mildew, it was thought desirable to use only pure sulfur and arsenate of lead, and later, if diluents seemed necessary from the point of view of expense, to use something that would not combine with the oxidation products of sulfur. Accordingly a very finely ground sulfur was used. In Plate XIII, Figs. 1 to 4, are shown respectively the ordinary flour sulfur, flowers of sulfur, the finely ground flour sulfur used in the present experiments, and sulfur precipitated by drying on a glass slide from lime-sulfur solution. It may be clearly seen that the sulfur used in the present experiments was much finer than the ordinary flour sulfur or even the flowers of sulfur, and compared favorably in fineness with that deposited by lime-sulfur solution. It was therefore hoped that if this finely ground sulfur were applied in sufficient quantity it would control the scab of apples, thus obtaining the advantages claimed for dusting and at the same time eliminating all tendency to injure foliage.

The injurious effects of lime-sulfur solution when applied to potato, grape, peach, and raspberry foliage are well known. Aside from a positive injury sometimes found on apple foliage, there is the further question as to whether a dwarfing effect does not occur under certain conditions.

EXPERIMENTS OF 1911

The first experiments with the use of dry sulfur to replace lime-sulfur solution were made by the writer in 1911. A number of different mixtures were applied in the form of dust in that year; but the work of the season was without results as far as the control of scab or of insects was concerned, since there were not enough of these pests in the orchard where the test was made to give any results as to their control. It was very noticeable, however, that the mixtures adhered remarkably well to the foliage and the fruit of the trees, and that there was no indication of foliage injury or dwarfing.

(1911) Scott, W. M., and Quaintance, A. L. Spraying peaches for the control of brown-rot, scab, and curculio. U. S. Agr. Dept. Farmers' bul. 440:21–40.
(1913) Blodgett, F. M. Hop mildew. Cornell Univ. Agr. Exp. Sta. Bul. 328: 298–299.

EXPERIMENTS OF 1912

During the following year the experiments were continued on a small scale. Instead of the hand machine used in the previous year, a traction machine was employed. This machine was not entirely satisfactory for use in an orchard. It was of the type used by the writer in the hop fields, in the experiments already mentioned, and since it was driven from the wheels it could not be stopped at the individual trees in order that a thorough application might be made. This was approximately accomplished, however, by making several trips around the rows of trees.

The whole orchard was sprayed once in the spring just as the buds were bursting (May 1), with lime-sulfur solution of dormant strength. The separate plats were afterward sprayed or dusted three times, on the following dates: May 15 to 16, May 31 to June 1, June 15.

The trees included in this experiment were principally Rhode Island Greenings and Northern Spies. Some of them were sprayed with lime-sulfur solution and lead arsenate; to others a dry mixture of flowers of sulfur and arsenate of lead was applied; to others sulfur and arsenate of lead were applied in suspension in water; and still others were left unsprayed. In this orchard very little apple scab developed either on the fruit or on the leaves of any of the trees, so that complete records were not made. However, in order that some indication might be obtained as to the degree of insect control secured and the control of what little scab there was, one tree of Rhode Island Greening apples from each block was picked and the apples were counted. The results of the counts are given in the following table:

TABLE 2. A CLASSIFICATION OF THE PICKED RHODE ISLAND GREENING APPLES FROM THE KINNE ORCHARD, HARTWICK SEMINARY, NEW YORK

Material used	Total number of apples	Sound		Unsound		Apple scab		Bud moth		Codling moth: Calyx entrance		Codling moth: Side entrance		Curculio		Aphis and red bug	
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Untreated...	399	15	3.8	384	96.2	37	9.3	23	5.8	148	37.1	55	13.8	292	73.2	17	4.3
Suspension of sulfur[1] and lead arsenate 1-50	2,890	2,383	82.5	507	17.5	3	0.1	90	3.1	98	3.4	143	4.9	122	4.2	88	3.0
Lime-sulfur 1-40 and lead arsenate 1-50[2] . .	689	507	73.6	182	26.4	5	0.7	21	3.0	39	5.7	39	5.7	36	5.2	61	8.9
Dry flowers of sulfur 10 and lead arsenate 1...	2,554	2,201	86.2	353	13.8	13	0.5	41	1.6	32	1.3	120	4.7	153	6.0	5	0.2

[1] In diluting this mixture, 2 gallons of a paste made of approximately 50 per cent water and 50 per cent finely ground sulfur was used to 50 gallons of water.

[2] The arsenate of lead used in these experiments was in the dry form. This would be equivalent to about 2 pounds of lead arsenate in paste form.

While in the above table only a relatively small number of apples are considered, yet the figures may be taken as giving some indication of the comparative value of the different treatments. It will be noted that on the unsprayed part of the orchard the percentage of scabby apples was only a little over nine. This mild attack of scab seemed to be controlled about equally well by the three different treatments used. The effectiveness of arsenate of lead seems to have been about equal when applied with the lime-sulfur solution and with the suspension of sulfur, as would of course be expected. In the dry mixture it seems to have been considerably more effective than in either of the liquid mixtures.

In so far, then, as could be judged from this year's experiments, the results were very favorable for the dust preparation.

EXPERIMENTS OF 1913

Although two years had passed with few results obtained on the control of scab by the use of a dust preparation, and although there was comparatively little scabby fruit in 1912, there seemed to be some prospect for results in 1913. The scab situation was summed up by Reddick (1913) as follows: "One might be tempted to conclude that 1913 will be a repetition of 1912 so far as scab is concerned. This is not so certain. This year we have made careful observations of the new infections occurring in August and September, and find that, while the fruit has rarely been attacked, a considerable number of new infections occurred on the foliage, and in some cases leaves have been found which were completely covered with the fungus. . . . . . If favorable rains occur and at the right time, there is every reason to expect a liberal sprinkling of scab in most orchards of the State next year."

With the prospect of more extensive scab infection in another year it was decided to continue the work in 1913 on a larger scale. Incidentally, a movement inaugurated to perform similar experiments in other States on a uniform plan afforded the advice and suggestions of a number of pathologists and entomologists in planning the experiments of the year. The selection and arrangement of plats was designed so as to eliminate as far as possible all experimental error. In brief, it was hoped to determine by these experiments the effectiveness of a dust mixture containing twenty per cent of dry powdered arsenate of lead and eighty per cent of finely divided sulfur, and of a paste — to be applied with water as a carrier — made up of free finely divided sulfur and arsenate of lead with a small quantity of a colloidal substance to aid in wetting the sulfur and the better to keep the sulfur and lead arsenate in suspension, as compared with the standard lime-sulfur solution with arsenate of lead and with an unsprayed check.

(1913) Reddick, Donald. Apple scab situation. West. New York Hort. Soc. Proc. 58: 86–89.

The arrangement of the variously treated plats can be seen from the accompanying diagrams. Each plat of trees was to be sprayed in the dormant state if necessary, and the individual plats were then to receive during the summer the treatments indicated below. It was planned tentatively to make four summer applications, following as closely as possible the general scheme of orchard treatment developed by various pathologists and entomologists in the State and fully detailed by Wallace (1913) in his monographic treatment of the apple-scab disease. All the treatments were to be made on the same day, however, or at least the difference in time of treatment was to be as small as possible and infection periods of the scab fungus were not to intervene between the treatment of the various plats. In determining the date of application the development of foliage and fruit, development of the scab fungus and of insects, and occurrence of general storm periods were to be followed closely, and an effort was to be made to apply the preparations before the arrival of the prolonged rains that frequently accompany such storm periods. The plats were to be treated as follows:

Plat 1. Commercial lime-sulfur solution diluted $2\frac{1}{2}$-100, and powdered arsenate of lead 2-100.

Plat 2. Finely ground sulfur [3] and powdered lead arsenate, mixed in the proportion of one part of lead arsenate [4] to four parts of sulfur; the quantity of mixture applied per acre to be 50 pounds (40 pounds of sulfur, 10 pounds of arsenate of lead).

Plat 3. Check. No summer treatment whatever.

Plat 4. To be sprayed with a paste containing the same materials as were used in plat 2, applied with water as a carrier at the rate of 14 pounds of paste (containing approximately 60 per cent dry sulfur) to 50 gallons of water to which $1\frac{3}{4}$ pound of powdered arsenate of lead was to be added just prior to use; the total application per acre to be approximately 300 gallons (equivalent to 40 pounds of sulfur, 10 pounds of arsenate of lead, per acre).

Owing to peculiarities of the season the schedule of applications usually recommended was not followed exactly, and because of unforeseen physical difficulties the quantities applied per acre were not always in accordance with the plan.

Details as to quantities of material used, dates of application and conditions influencing the same, time required, comparative costs, results, and methods of recording data, will be given in connection with the individual experiments.

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[3] The sulfur was so finely ground that at least 95 per cent would pass through a 200-mesh sieve. The method of testing sulfur is described by the writer in Bulletin 328 of the Cornell University Agricultural Experiment Station.

[4] It will be remembered that a mixture containing one part of arsenate of lead to nine parts of sulfur apparently gave satisfactory control of insects in the experiments of 1912. Inasmuch as the fungicidal value of the sulfur seemed to be the important consideration, it was thought desirable to use an insecticide somewhat in excess this year in order that no possible insect pests might interfere with the work.

(1913) Wallace, Errett. Scab disease of apples. Cornell Univ. Agr. Exp. Sta. Bul. 335: 545–624.

Experiments in Catchpole orchard at North Rose

The experimental orchard at North Rose consisted of a block of Rhode Island Greening trees, seven rows wide and seventeen rows long, with other apples on three sides as shown in Fig. 17. One or two rows of other

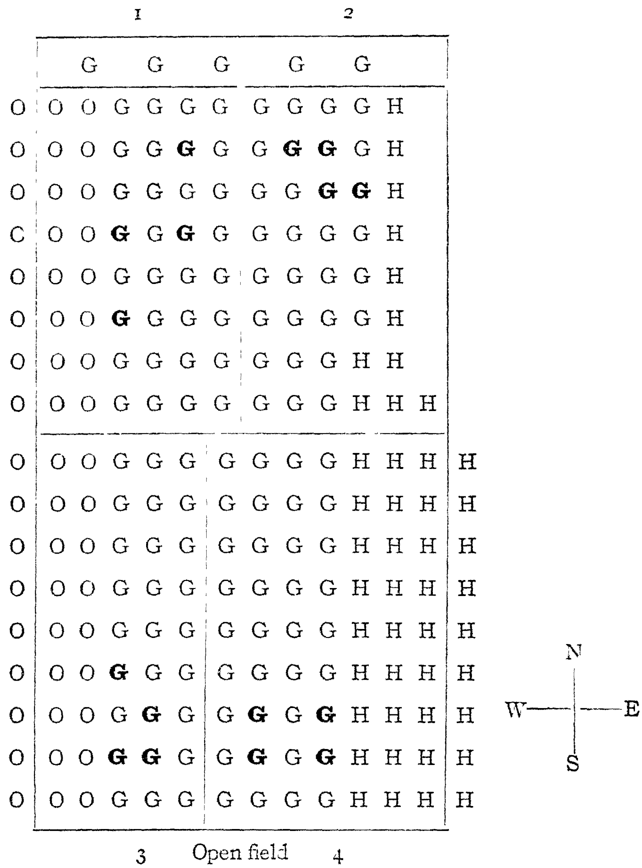

FIG. 17.— *Chart showing plan of the experiment performed in the Catchpole orchard, North Rose, New York. The Rhode Island Greening trees (G) enclosed in the black lines represent trees from which the commercial yield was determined, and the trees indicated by bold-faced type are the trees from which the apples were counted. G, Rhode Island Greening; H, Hubbardston; O, Oldenburg*

varieties were included in the plats in order to make them wide enough to leave an area of count trees in the center protected from migration of insects from surrounding plats by trees sprayed in the same way. The bold-faced letters on the map indicate count trees. These were chosen because of similar location, and were trees of about equal size and con-

dition of growth. The plats were made large enough so that usually it was not necessary to use adjacent trees for counting, although this was necessary in some cases.

The block included approximately 126 trees, about twenty years of age, planted 33 by 33 feet apart. The orchard had been cultivated between the rows, with an uncultivated part directly under the trees which was mulched. The orchard is mostly level, but has a ravine running into it on the center of the east side. It will be noticed that the count trees are at the opposite ends of the plat, so that none of them were in this low

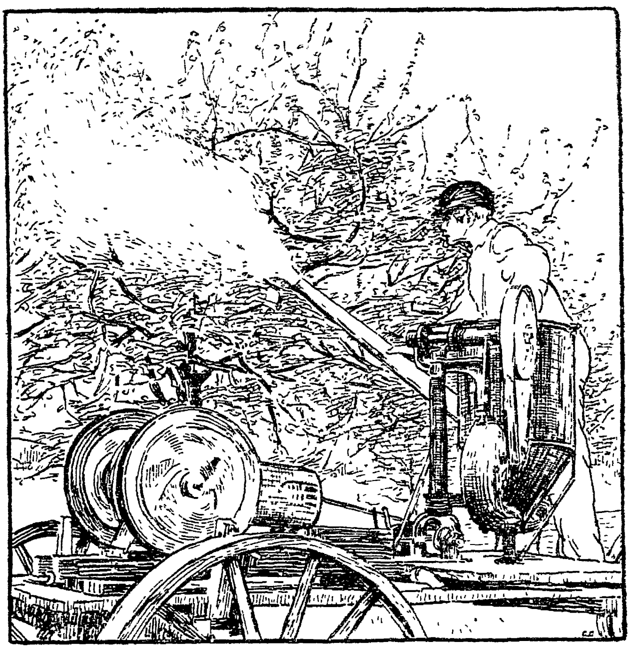

FIG. 18.— *Dusting outfit in operation. Pen sketch from a photograph*

place. The trees at the top of the bank in the south end of the dust block were not thrifty because the topsoil, which was sandy, had been blown away. These were also avoided as count trees, as may be seen.

Methods and materials used

The liquid mixtures used in this orchard were applied with a power spraying outfit carrying a pressure of 120 to 140 pounds, with three men and three horses for its operation. The dust mixture was applied with a large power outfit (Fig. 18) manufactured by the Dust Sprayer Manufacturing Company, Kansas City, Missouri, operated by a $1\frac{1}{2}$-horse-power "New

Way" gasoline engine. This engine caused considerable difficulty in the work because it was not large enough. A dormant spray of winter-strength lime-sulfur solution was applied to the entire block Three summer applications were made with each of the different preparations tried: the first just before the blossom buds opened, the second when the petals were about one half off, the third four weeks later. The last application was delayed because codling moths appeared very late this year. In Table 3 are shown the dates, amounts of spray material used, and other data, for the different applications.

The cost figures given in the table are calculated on the basis of horse labor at 10 cents per hour, man labor at 20 cents per hour, lime-sulfur solution at 14 cents per gallon, dry arsenate of lead at 18 cents per pound, and sulfur at $2.10 per hundred. Of course these figures are more or less arbitrary. The cost of the deterioration of the machine is not taken into account. At the above figures the diluted lime-sulfur mixture would be worth 98 cents per 100 gallons, the paste 92 cents per 100 gallons (this does not include cost of preparation), and the dry mixture $5.28 per 100 pounds.[5]

It will be noticed that in the first application of the dry mixture nearly twice as much of the mixture was used as in either of the succeeding applications. This was largely due to difficulty with the engine, which stopped frequently or ran so slowly that much material was wasted in trying to make a satisfactory application. It is doubtful whether the first application was any more thorough than either of the succeeding ones, the surplus quantity of the mixture being largely wasted. The last two applications were made with less waste of time; but there is good reason to believe that even these applications could have been made with less material and in a shorter time if the engine had been large enough to run the machine steadily and at a slightly higher speed.

It will be noticed that although the cost of application of the dust mixture was considerably less than the cost of application of the liquid mixture, the cost of the mixture itself was very high in comparison with that of the liquid mixture. This may be attributed to two causes, namely, the large quantity of arsenate of lead in the mixture and the large quantity of mixture applied. It has been noted above that in planning these experiments 300 gallons of liquid spray was to be applied per acre at each application, and 50 pounds of the dry mixture. This was not accomplished in practice. On the other hand, in operating the dusting machine so much material was lost while the engine was running badly that more than the quantity of dust specified was used before the operators were satisfied.

[5] According to the original plan, using 300 gallons of spray per acre and 50 pounds of dust, the cost per acre would have been $2.94 for lime-sulfur solution, $2.76 for the suspension sulfur, and $2.64 for the dust mixture.

TABLE 3. DATA ON TIME AND METHODS OF APPLICATION, CATCHPOLE ORCHARD, NORTH ROSE, NEW YORK

Date of application	Plat	Number of trees	Material used, and strength	Quantity used	Time required: Horse Hrs.	Horse Min.	Man Hrs.	Man Min.	Machine Hrs.	Machine Min.	Cost: Labor	Cost: Material	Cost: Total cost	Cost per tree
				(Gals.)										
May 3	1	48	Lime-sulfur 1–33; lead arsenate 7 pounds–200 gallons	190	2	...	2	.	1	.	$0 60	$2 00	$2 60	$0 054
May 14	1	48	Lime-sulfur 1–33; lead arsenate 7 pounds–200 gallons	150	3	..	3		1	...	0 90	1 57	2 47	0 051
June 11	1	48	Lime-sulfur 1–33; lead arsenate 7 pounds–200 gallons	160	2	09	2	09	0	43	0 65	1 68	2 33	0 049
Totals.	.	.	...	500	7	09	7	09	2	43	$2 15	$5 25	$7 40	$0 154
				(Lbs.)										
May 3	2	41	Dry sulfur and lead arsenate 4:1	140	2	.	2		1		$0 60	$ 7 40	$ 8 00	$0 195
May 14.	2	41	Dry sulfur and lead arsenate 4:1	76	1	32	1	32	0	46	0 45	4 01	4 46	0 109
June 11.	2	41	Dry sulfur and lead arsenate 4:1	85	0	54	0	54	0	27	0 30	4 48	4 78	0 117
Totals.	.	.	...	301	4	26	4	26	2	13	$1 35	$15 89	$17 24	$0 421
				(Gals.)										
May 3	4	56	Paste sulfur 24; lead arsenate 3.5 lbs.–100 gals.	200	2	.	2	.	1	..	$0 60	$1 84	$2 44	$0 044
May 14.	4	56	Paste sulfur 24; lead arsenate 3.5 lbs.–100 gals.	180	3	15	3	15	1	05	0 98	1 66	2 64	0 047
June 11	4	56	Paste sulfur 24; lead arsenate 3.5 lbs.–100 gals.	185	2	30	2	30	0	50	0.75	1 70	2 45	0 044
Totals.	..	....	...	565	7	45	7	45	2	55	$2.33	$5 20	$7 53	$0 135

was thought more desirable for the present year to apply an amount fficient to insure results if the mixture were effective at all. As will be own later, the dust mixture was considerably more effective against sects than was the lime-sulfur and arsenate-of-lead mixture in every se; so that possibly a smaller quantity of lead might have been used. nere is, therefore, good reason to believe that the cost of the dust applica- ons may be reduced to the same amount as the cost of applying lime- ılfur as a liquid spray, if not lower. This will be the object of work ıring the coming year.

Veather records

No record was kept of weather conditions as they occurred in this rchard, with the exception of notes on a few of the rains that correspond rith the record given below. However, the record (Table 4) of the Roch- ster branch of the United States Weather Bureau may be taken as indicat- ng the principal periods during which infection occurred.

TABLE 4. TRANSCRIPT OF RECORDS TAKEN AT THE ROCHESTER STATION OF THE WEATHER BUREAU OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

Date	Precipitation (inches)	Weather conditions
April 27	.78	....
April 28	.19	....
May 15	T*	Cloudy
May 16	.02	Cloudy
May 17	0	Partly cloudy
May 18	.15	Partly cloudy
May 21	.06	Cloudy
May 22	.73	Cloudy
May 23	.04	Cloudy
May 24	T	Cloudy
May 25	T	Cloudy
May 27	.95	Cloudy
May 28	.64	Partly cloudy
May 31	T	Partly cloudy
June 1	.72	Partly cloudy
June 6	0	Cloudy
June 7	.22	Cloudy
June 8	0	Cloudy
June 19	.02	Cloudy
June 20	.12	Cloudy
June 21	0	Cloudy
June 25	.14	Clear
June 26	T	Cloudy
June 27	.86	Partly cloudy

* Trace; an amount less than .01 inch, too small to be measured.

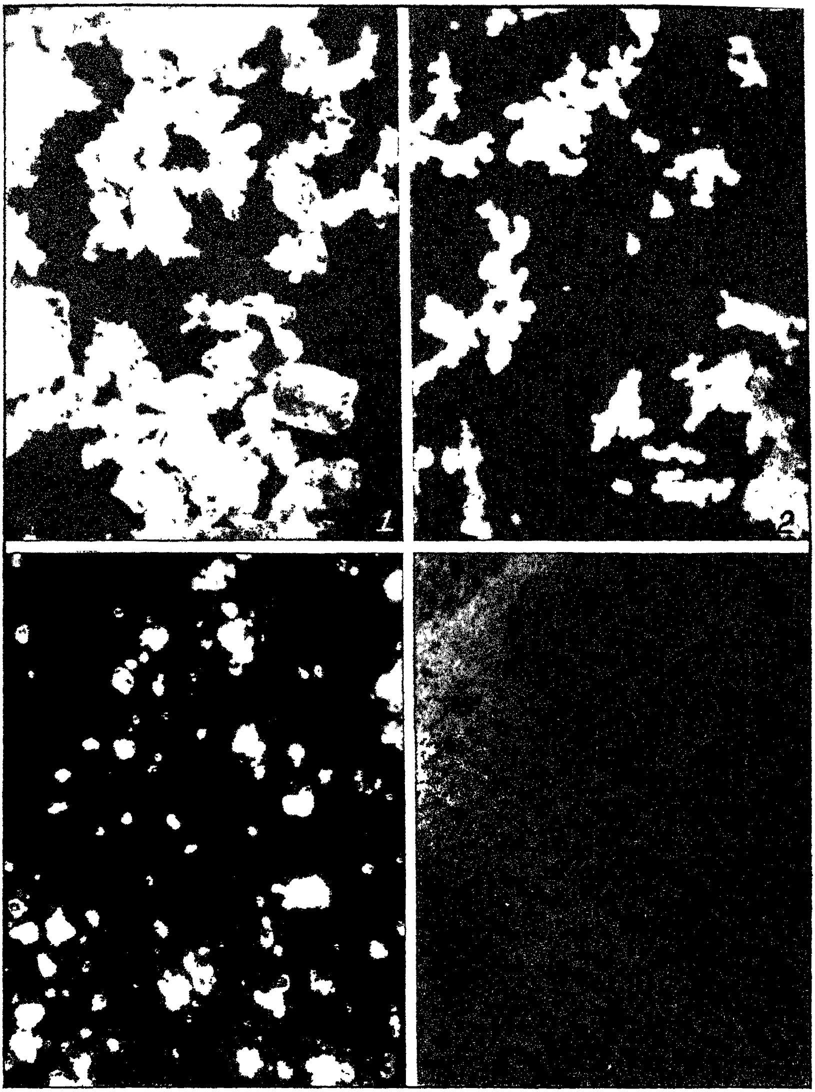

PLATE XIII.— *Various forms of sulfur*

FIG. 1.— *Ordinary flour sulfur*
FIG. 2.— *Ordinary flowers of sulfur used in experiments of 1912*
FIG. 3.— *Finely ground sulfur used in experiments of 1913*
FIG. 4.— *Sulfur precipitated by exposing lime-sulfur solution to the air*

All photomicrographs made with the same combination of lenses. In Figs. 1, 2, and the photographs were made with reflected light, in Fig. 4 with transmitted light

That the first infection occurred during the rainy period from May 15 to May 18 is in accord with observations made in the orchard. The next prolonged infection period was clearly from May 21 to May 25, with two shorter periods near the end of the month. These dates constituted the principal scab-infection periods of the season.

Results of experiments

According to the original plans, the drops from the different plats were to be counted during the summer. Owing to a lack of rainfall of sufficient duration to permit infection from the time when the blossom clusters began to spread until two weeks after the blossoms were off, no pedicel infection occurred. The codling moth did not make its appearance until very late and then not in large numbers, so that there were very few drops due to attacks by this insect.[6]

An inspection of the orchard made on July 24 showed certainly that all the treatments had proved somewhat effective as compared with the check. Some counts were made, which showed about 15 per cent scab infection on the lime-sulfur-treated plat, about 25 per cent on the dusted plat, and 50 per cent on the check. Insect injuries were exceedingly abundant on the check plat but were much less on the treated plats.

The apples were picked and graded during the week of September 18 to 24. Four nonadjacent trees were selected from the inner protected area of each plat, from which the apples were picked, and a careful tabulation was made of the different injuries occurring on each apple and also on the apples picked up under the trees at that time. The apples from each lot of count trees, together with the apples from the remainder of each plat, were then separated into commercial grades by the same men who had picked the apples. The method of grading was the same as that employed in the other orchards owned by the same grower.

In making the tabulation the apples were first divided into sound and unsound. The unsound apples were further classified, each individual apple falling under one to five headings, depending on whether or not it was affected with scab, whether or not spring caterpillars had attacked it, whether or not codling moth had entered at the side or at the end, and whether or not curculio had punctured it.

Each apple showing any trace of scab, even though only a small spot near the calyx end, was listed as scabby. Each apple bearing innumerable scab spots likewise was counted as only one in the tabulation. While this is by no means a fair way of determining the relative amount of scab, yet it did not seem practicable to count each individual spot.

[6] The majority of the drops for the season, therefore, are included in Table 6, since the excessively dry summer prevented them from rotting.

TABLE 5. A CLASSIFICATION OF THE PICKED RHODE ISLAND GREENING APPLES FROM THE CATCHPOLE ORCHARD

Treatment	Total number of apples	Sound		Unsound		Apple scab		Bud moth and other spring caterpillars		Codling moth		Codling moth				Curculio	
												Side entrance		Calyx entrance			
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Unsprayed	1,581	56	3.5	1,525	96.5	1,373	86.8	733	46.1	242	15.3	190	12.0	112	7.1	44	2.78
	1,445	188	13.0	1,257	87.0	963	66.6	598	41.4	145	10.0	117	8.1	58	4.0	76	5.26
	1,613	58	3.6	1,555	96.4	1,442	89.4	572	35.5	257	15.9	233	14.4	126	7.8	74	4.59
	1,724	172	10.0	1,552	90.0	1,315	76.3	593	34.4	138	8.0	105	6.1	68	3.9	59	3.42
Total	6,363																
Average			7.5		92.5		79.8		39.4		12.3		10.2		5.7		4.01
Probable error			±1.38		±1.38		±3.04		±1.6		±1.14		±1.1		±0.68		±0.317
Suspension of sulfur and lead arsenate	3,254	2,019	62.0	1,235	38.0	1,045	32.1	268	8.2	13	0.4	10	0.3	1	0.03	16	0.49
	1,434	970	67.6	464	32.4	381	26.6	137	9.6	6	0.4	9	0.6	1	0.07	6	0.42
	3,157	2,046	64.8	1,111	35.2	983	31.1	205	6.5	17	0.5	21	0.7	1	0.03	5	0.16
	3,528	2,141	60.7	1,387	39.3	1,206	34.2	331	9.4	35	1.0	43	1.2	2	0.06	16	0.45
Total	11,373																
Average			63.8		36.2		31.0		8.4		0.6		0.7		0.05		0.38
Probable error			±0.889		±0.889		±0.94		±0.414		±0.08		±1.09		±0.0056		±0.04
Lime-sulfur and lead arsenate	1,383	598	43.2	785	56.8	493	35.6	453	32.8	33	2.4	35	2.5	3	0.22	10	0.72
	2,493	1,499	60.1	994	39.9	697	28.0	472	18.9	26	1.0	25	1.0	4	0.16	4	0.16
	2,504	1,951	77.9	553	22.1	218	8.7	352	14.1	25	1.0	33	1.3	1	0.04	10	0.40
	2,484	1,564	63.0	920	37.0	287	11.6	696	28.0	26	1.0	30	1.2	2	0.08	16	0.64
Total	8,864																
Average			61.0		39.0		21.0		23.5		1.4		1.5		0.13		0.48
Probable error			±4.16		±4.16		±3.78		±2.48		±0.198		±0.2		±0.02		±0.07
Dry sulfur and lead arsenate	2,529	1,949	77.1	580	22.9	512	20.2	86	3.4	10	0.4	11	0.4	0	0	4	0.16
	3,117	1,694	54.3	1,423	45.7	1,346	43.2	135	4.3	10	0.3	11	0.4	0	0	1	0.03
	1,816	1,158	63.8	658	36.2	601	33.1	88	4.8	12	0.7	13	0.7	0	0	5	0.28
	3,538	2,100	59.4	1,438	40.6	1,320	37.3	170	4.8	8	0.2	10	0.3	0	0	3	0.08
Total	11,000																
Average			63.7		36.3		33.5		4.3		0.4		0.5		0		0.14
Probable error			±2.85		±2.85		±2.8		±0.196		±0.17		±0.05		±0		±0.03

TABLE 6. A CLASSIFICATION OF THE DROP APPLES PICKED UP AT HARVEST TIME FROM THE CATCHPOLE ORCHARD

Treatment	Total number of apples	Sound		Unsound		Apple scab		Bud moth and other spring caterpillars		Codling moth		Codling moth				Curculio	
												Side entrance		Calyx entrance			
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Unsprayed	219	12	5.5	207	94.5	167	76.3	85	38.8	31	14.2	37	16.9	8	3.7	0	2.7
	275	52	18.9	223	81.1	163	59.3	92	33.5	21	7.6	17	6.2	10	3.6	18	6.[illegible]
	277	12	4.3	265	95.7	239	80.3	72	26.0	73	20.4	82	20.6	33	11.0	10	3.6
	249	36	14.5	213	85.5	157	63.1	78	31.3	37	14.9	23	9.2	20	8.0	14	5.6
Total	1,020																
Average			10.8		89.2		71.3		32.4		15.8		15.5		6.8		4.6
Probable error			±2.06		±2.06		±2.58		±1.3		±2.2		±3.0[illegible]		±1.2		±0.5
Suspension of sulfur and lead arsenate	256	157	61.3	99	38.7	63	24.6	38	14.8	12	4.7	12	4.7	1	0.4	3	1.[illegible]
	167	92	55.1	75	44.9	43	25.7	29	17.4	18	10.8	19	11.4	0	0	0	0
	75	27	36.0	48	64.0	31	41.3	22	29.3	14	18.7	15	20.0	0	0	[illegible]	2.7
Total	498																
Average			50.8		49.2		30.5		20.5		11.4		12.0		0.1		1.3
Probable error			±4.2		±4.2		±3.0		±2.16		±2.2		±2.11		±0.07		±0.4
Lime-sulfur and lead arsenate	291	93	32.0	198	68.0	107	36.8	117	40.2	18	6.2	20	6.9	1	0.3	3	1.0
	254	157	61.8	97	38.2	71	28.0	36	14.2	12	4.7	12	4.7	1	0.4	0	0
	150	107	71.3	43	28.7	10	6.7	34	22.7	5	3.3	5	3.3	0	0	1	0.7
	251	122	48.6	129	51.4	22	8.8	109	43.4	16	6.4	10	6.4	1	0.4	0	0
Total	946																
Average			53.4		46.6		20.1		30.1		5.2		5.3		0.3		0.4
Probable error			±5.0		±5.0		±4.3		±3.68		±0.35		±0.17		±0.056		±0.15
Dry sulfur and lead arsenate	139	98	70.5	41	29.5	27	19.4	15	10.8	4	2.0	4	2.0	1	0.7	0	0
	174	85	48.9	89	51.1	71	40.8	30	17.2	4	2.3	4	2.3	0	0	0	0
Total	313																
Average			59.7		40.3		30.1		14.0		2.6		2.6		0.4		0
Probable error			±5.17		±5.17		±5.09		±1.54		±0.14		±0.11		±0.19		±0

Among the spring caterpillars, bud moth was by far the most troublesome; green fruit worms, green leaf rollers, and others, however, were also present.

In tabulating the injuries caused by the codling moth the total number of affected apples is listed, followed by the actual number of larvæ entering at the side of the apple.

Since the apples were only slightly affected by curculio, no account was taken as to whether there was one mark or several marks on each apple.

In order to show the relative value of the different materials used as insecticides and fungicides, the percentages of the apples from each tree affected with each of the various insects and with apple scab have been computed, together with the average, or mean, of these figures and the probable error[7] of the mean.

Scab control.— From tables 5 and 6 it may be seen that all three treatments used reduced the amount of scab decidedly below the amount on the untreated plat. The difference between the average of the check and the average of each of the sprayed plats, with a probable error of ± 3 per cent, shows plainly that all the mixtures applied had a very decided fungicidal action. The difference between the suspension of sulfur and sulfur applied as a dust is so slight as to be negligible, since it is smaller than the probable error. The lime-sulfur plat shows the lowest average percentage of scab, but its superiority in this respect is not very certain because of the large variation in the amount of scab on the different trees. The probable error is large and would indicate that there is an even chance that the true mean would lie between 16 and 25 per cent. The indications are, then, that the lime-sulfur is slightly superior as a fungicide, but this is not entirely certain.

In the table showing the percentages of drop apples, exactly the same differences may be pointed out except that here the variation between the different trees and the probable error are even greater. The sprayed plats, however, all show a decided control of scab as compared with the unsprayed plat.

It should not be understood that in any of the sprayed plats a remarkably good control of scab was secured; but this does not make less valuable the comparison between the different materials used. The somewhat high percentage of scabby apples in all sprayed plats is attributed rather to the fact that the third application of spray was delayed because of the late emergence of the codling moth, than to poor action of the materials used. Since this was the period during which most of the apple-

[7] The probable error added to and subtracted from the mean gives the limits between which it is an even chance that the true mean lies. There is also an even chance that the true mean lies outside of this range. It is improbable, however, that an error will be many times as large as the probable error.

scab infection took place this summer, another application made in the interval between the second and the third application would undoubtedly have been very valuable.

Insect control.— It may be seen from the tables that the insects causing most injury to the apples in this orchard this year were those classified under the head of "Bud moth and other spring caterpillars"; these include leaf-rollers, green fruit worms, and others. The figures indicate that in the unsprayed block the true average would be between 38 and 41 per cent of picked apples injured by these insects. On the unsprayed block only about 12 per cent of the picked apples were injured by codling moth, and 4 per cent by curculio. It will be noticed that the best control of each of these insects was secured on the dusted plat. It is difficult to understand why there should have been so large a difference in insect control between arsenate of lead applied with lime-sulfur and that applied with suspension of sulfur.

The counts from the drops of this block confirm the results obtained from the counts of the picked apples. There is a higher percentage of injuries on the drops, which of course was to be expected. The dusted apples appear the best throughout with respect to insect control, with the possible exception of those in which codling moth larvæ entered the calyx; in that case, however, the probable error is so large in comparison with the difference in percentages between the various mixtures as to render worthless any comparison based on these figures.

Sound and unsound fruit.— From the figures in the tables it may be seen that in total percentages of sound and unsound picked apples there was no dependable difference between the various mixtures used. The averages are slightly against the lime-sulfur spray; but the difference in each case is less than the probable error, so that it is of no importance. All the sprayed plats had about 56 per cent more sound apples than the unsprayed plat had.

These figures are reflected in the commercial grading so far as it is available. Due to a misunderstanding, the record of the commercial yield of the lime-sulfur plat was partially lost and unfortunately it cannot be included here.

The graders, without knowing of the different treatments, stated that the apples from the dusted block looked better on the table and packed a higher percentage of No. 1 apples. This may be attributed to the more effective insect control — since the percentage of scab was actually higher than in the apples receiving liquid spray — and to the fact that minute scab spots were overlooked by the packers.

The apples from the check block were of evaporator-stock quality, but on a rising market they were disposed of in barrels at a considerably reduced price.

Experiments in Lawson orchard at Owego

This orchard is located about four miles north of Owego and about two miles from Flemingville. The orchard is situated so that it slopes gently toward the east. It is twenty years old and has been in sod for a number of years; it was not cultivated this year, but hogs were allowed to run in it during the summer. The trees were generally in good condition, with little deadwood, although they were not making much growth. The orchard had never been sprayed. The year before it had borne a good crop of apples which were very scabby. Ben Davis apples kept until spring and examined by the writer in March were nearly all scabby, and some were almost covered with scab spots.

Enough fruit buds were present to give a prospect for a fair set of fruit; comparatively little fruit set, however, probably due to the frosts and the cold weather at blossoming time — the temperature being 26° F. one night during blossoming. The experiments were first outlined so as to include a block of Northern Spy and a block of Ben Davis apples. The experiments in the Ben Davis block were later altered so as to omit some of the Ben Davis apples, owing to a poor prospect for fruit, and to include some Tompkins Kings. It will be seen from the charts (Figs. 19 and 20) that this experiment was planned on a large scale, the plats being large enough to leave, in most cases, two rows through the center from which to select count trees.

Methods and materials used

The dusting machine employed here was like that used in the Catchpole orchard. While a $1\frac{1}{2}$-power engine was said to be sufficient to run one of these machines, it proved to be rather too light to do satisfactory work. The engine was working so near its capacity that if for any reason it missed a stroke or two it stopped; also, since it was carrying about the maximum load, there was a tendency for it to heat rapidly. It was difficult to obtain data as to the time required for dusting the trees, because of this frequent difficulty with the engine.

The liquid-spray machine used was a small power apparatus fitted up by the grower, and worked satisfactorily. The spraying was all done from the ground with 10-foot spray rods. This was fairly satisfactory, since the trees were comparatively small and headed low.

In performing this experiment various difficulties were met with which led to deviations from the original plan of execution and to rather poor results; these will be given for what they are worth, since they are of value in comparing the different methods quite as much as though better results had been obtained. In the first place, the liquid spray machine was not ready in time for the first application on the Ben Davis and

Tompkins King block; but, owing to the fact that the Northern Spies were later, the first application was made on those The Tompkins King and the Ben Davis apples therefore, received the application just as the blossoms were falling and another application about four weeks later. The Northern Spies received an application just before the blossoms opened and one as the petals were falling. When the time arrived for the third application it was omitted, because there were not enough apples on the trees to make it worth while. While this was undoubtedly true from a commercial standpoint, yet there was rather more fruit set on the trees than was thought; the fruit had been hidden by the dense foliage which characterizes this variety, so that it was thought worth while to pick and examine the apples in order to get some knowledge of the comparative value of the mixtures applied

By reference to the map of this orchard (Figs. 19 and 20) it will be seen that two separate sets of plats to be sprayed were laid out, one including

B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	4
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	3
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	2
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	1
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	
B	B	B	B	B	B	B	B	S	S	K	K	K	K	A	A	

N
W — E
S

FIG. 19.— *Chart showing plan of the experiment performed in the Lawson orchard, Owego, New York. The trees enclosed in the black line represent the different plats: 1, dusted; 2, sprayed with lime-sulfur solution; 3, sprayed with suspension sulfur; 4, untreated. A, Pewaukee; B, Ben Davis; S, Northern Spy; K, Tompkins King*

1				2				3			4			
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
S	S	S	S	S	O	S	S	S	O	S	S	S	O	S
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
S	S	S	S	S	S	S	O	S	S	S	S	S	S	S
S	S	S	P	S	S	S	S	S	S	O	S	S	S	S
S	S	S	O	P	P	P	P	S	S	S	S	S	S	S
S	S	S	S	S	O	O	S	S	S	S	P	S	S	S
S	S	S	S	S	S	S	S	S	S	S	S	S	O	S
S	S	S	O	S	S	O	S	S	S	S	O	S	S	S
S	S	S	S	S	S	O	S	S	S	P	S	S	S	S

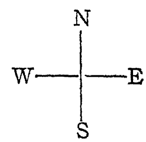

FIG. 20.— *Chart showing plan of the experiment performed in the Lawson orchard, Owego, New York. The trees enclosed in the black lines represent the different plats: 1, sprayed with lime-sulfur; 2, sprayed with suspension sulfur; 3, untreated; 4, dusted. S, Northern Spy; O, missing trees; P, poor trees*

the Ben Davis and the Tompkins King apples and the other the Northern Spies. The data for the quantities of material applied and the cost for these two sets of plats are given separately; those for the Tompkins King and the Ben Davis are given together. Thus, while the quantity of spray material and the costs were based on this entire block, the Tompkins King apples only were picked and examined. The data for the block of Ben Davis and Tompkins King apples are given in Table 7.

Weather records

A record of the temperature and the rainfall at this farm during the summer was made by Mr. Lawson. The data given in Table 8 are copied from that record.

The first infection probably took place at about the same time as in the Catchpole orchard, namely, from May 16 to May 18, since the first scab spots became apparent on the foliage at about the same time. There was also an infection period from May 22 to May 27 when further infections undoubtedly occurred.

Results of experiments, Tompkins King apples

In the first block of apples careful counts were made only of the Tompkins Kings. The apples on the trees from which careful counts were made were picked on October 3 and the commercial sorting was completed on

TABLE 7.— DATA ON TIME AND METHODS OF APPLICATION, TOMPKINS KING AND BEN DAVIS APPLES, LAWSON ORCHARD, OWEGO, NEW YORK

Date of application	Number of trees	Material used, and strength	Quantity used	Time required: Horse Hrs.	Horse Min.	Man Hrs.	Man Min.	Machine Hrs.	Machine Min.	Cost: Labor	Material	Total cost	Cost per tree
			(Gals.)										
May 15..	56	Lime-sulfur 1-40; lead arsenate 3.5 pounds-100 gallons . . .	150	3	15	4	57	1	39	$1 32	$1 47	$2 79	$0 050
June 12..	56	Lime-sulfur 1-40; lead arsenate 3.5 pounds-100 gallons....	150	4	00	6	00	2	00	1 60	1 47	3 07	0 055
Totals..	....	....	300	7	15	10	57	3	39	$2 92	$2 94	$5 86	$0 105
			(Lbs.)										
May 15..	56	Dry sulfur and arsenate of lead 4:1.	96	1	00	1	00	0	30	$0 30	$5 07	$5 37	$0 096
June 13..	56	Dry sulfur and arsenate of lead 4:1................	75	1	10	1	10	0	35	0 35	3 96	4 31	0 077
Totals..	...	....	171	2	10	2	10	1	5	$0 65	$9 03	$9 68	$0 173
			(Gals.)										
May 15..	56	Paste sulfur 24; lead arsenate 3.5 pounds-100 gallons.....	150	2	56	4	24	1	28	$1 17	$1 38	$2 55	$0 045
June 12..	56	Paste sulfur 24; lead arsenate 3.5 pounds-100 gallons.....	150	3	30	5	15	1	45	1 40	1.38	2 78	0 050
Totals..	....	....	300	6	26	9	39	3	13	$2 57	$2.76	$5.33	$0 095

October 8. The yield on these trees was very light, due to the frosts in the spring which prevented a good set of fruit. On the unsprayed plat, especially, there was very little fruit, much less than on any of the other plats. This scarcity of fruit was apparently brought about by various insects. On some of the trees the apple-tree tent-caterpillar worked so much damage as to leave practically no apples. The counts of apples on the unsprayed plat are practically of no value because of the few apples on which they are based. While there were comparatively few apples on all the plats, it seems fairly certain that the difference in number of

TABLE 8. TRANSCRIPT FROM WEATHER RECORD AT LAWSON FARM

Date	Duration of rainfall	Precipitation (inches)
May 6	4 to 7 p. m	.040
May 9	6 to 7 a. m	.045
May 16	7 a. m	.030
May 18	7 a. m. to 2 p. m	.013
May 22 } May 23 }	7 a. m May 22 to 12 p. m. May 23	1.620
May 25		.170
May 27	8 p. m. to 12 m	1.040
June 1		.060
June 7		.020
June 20	4 to 6 p. m	.510
June 27	5 to 7 a. m	.490
July 9	All day	.860
July 26		1.660

apples between the unsprayed plat and the plats adjoining it was due principally to the effect of the spray mixture applied.

Although the unsprayed plat of this block of trees yielded so few apples as to be worthless as a check, the percentages of apples injured by various insects are given as being of some value as a comparison, especially since they agree in a general way with the results obtained in the Catchpole orchard. Of course it must be remembered that in this block of trees the first application was omitted because the apparatus was not ready in time. The control was therefore not nearly so good as it would have been if more applications had been made; but the comparison between the different materials should be almost, if not quite, as good as though better control had been secured. In fact, it has not infrequently happened that when several different materials were applied, practically perfect control was secured in all cases; so that one is led to believe that the conditions were not strenuous enough to really test the materials.

The following tables show the percentages of apples injured by various insects and by apple scab as computed from the above experiments, with the averages for the different plats:

TABLE 9. A CLASSIFICATION OF THE PICKED TOMPKINS KING APPLES FROM THE LAWSON ORCHARD

Treatment	Total number of apples	Sound: Number	Sound: Percentage	Unsound: Number	Unsound: Percentage	Apple scab: Number	Apple scab: Percentage	Bud moth and other spring caterpillars: Number	Bud moth and other spring caterpillars: Percentage	Codling moth: Number	Codling moth: Percentage	Codling moth, Side entrance: Number	Codling moth, Side entrance: Percentage	Codling moth, Calyx entrance: Number	Codling moth, Calyx entrance: Percentage	Curculio: Number	Curculio: Percentage
Unsprayed[8]	64	7	10.9	57	89.1	14	21.9	53	82.8	13	20.3	8	12.5	7	10.9	1	1.6
Suspension of sulfur and lead arsenate	385	191	50.4	101	49.6	101	26.2	108	28.1	16	4.2	10	2.6	0	0	8	2.1
	198	72	36.4	126	63.6	60	30.3	78	39.4	11	5.6	10	5.1	2	1.0	3	1.5
	230[9]	110	47.8	120	52.2	23	10.0	89	38.7	20	11.3	28	12.2	0	0	2	0.9
Total	813																
Average			41.0		55.1		22.2		35.4		7.0		7.4		0.3		1.5
Probable error			±2.1		±2.1		±2.0		±2.0		±0.61		±0.678		±0.17		±0.10
Lime-sulfur and lead arsenate	150	65	43.3	85	56.7	52	34.7	38	25.3	19	12.7	23	15.3	2	1.3	7	4.7
	129	65	50.4	64	49.6	22	17.1	44	34.1	7	5.4	8	6.2	0	0	0	0
	408	124	30.4	284	69.6	113	27.7	210	51.5	27	6.6	31	7.6	0	0	21	5.1
	100	47	47.0	53	53.0	20	20.0	40	40.0	2	2.0	1	1.0	1	1.0	3	3.0
Total	787																
Average			42.8		57.2		24.9		39.2		6.7		7.5		0.6		3.2
Probable error			±2.55		±2.55		±3.3		±3.4		±0.3		±1.7		±0.[illegible]		±0.[illegible]
Dry sulfur and lead arsenate	494	207	41.9	287	58.1	222	44.9	108	21.9	15	3.0	17	3.4	1	0.2	10	2.0
	554	284	51.3	270	48.7	155	28.0	122	22.0	22	4.0	31	5.6	1	0.2	18	3.2
	754	339	45.0	415	55.0	216	28.6	228	30.2	33	4.4	32	4.2	1	0.1	10	1.3
	250	111	44.4	139	55.6	95	38.0	57	22.8	11	4.4	12	4.8	0	0	3	1.2
Total	2,052																
Average			45.7		54.3		34.9		24.2		4.2		4.5		0.1		1.9
Probable error			±1.2		±1.2		±2.2		±1.2		±0.23		±0.08		±0.02		±0.3

[8] All of the two inner of the unsprayed rows of trees, eight trees all together, are included in this tabulation as one tree.
[9] Three trees were picked together in this plot, from which these figures were taken.

TABLE 10. A CLASSIFICATION OF THE DROP APPLES PICKED UP AT HARVEST TIME FROM THE LAWSON ORCHARD

Treatment	Total number of apples	Sound		Unsound		Apple scab		Bud moth and other spring caterpillars		Codling moth		Codling moth				Curculio	
												Side entrance		Calyx entrance			
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Unsprayed[8]	6	0	0	6	100.0	2	33.3	4	66.7	2	33.3	2	33.3	1	16.7	0	0
Suspension of sulfur and lead arsenate	59	23	39.0	36	61.0	13	22.0	26	44.1	7	11.9	8	13.6	0	0	2	3.4
	22[9]	5	22.7	17	77.3	4	18.2	14	63.6	3	13.6	3	13.6	0	0	0	0
	17[9]	4	23.5	13	76.5	3	17.6	10	58.8	3	17.6	4	23.5	0	0	1	5.9
Total	98																
Average			28.4		71.6		19.3		55.5		14.4		16.9		0		3.1
Probable error			±2.5		±2.5		±0.89		±3.3		±0.93		±1.7		±0		±0.94
Lime-sulfur and lead arsenate	38	11	28.9	27	71.1	11	28.9	17	44.7	9	23.7	10	26.3	0	0	1	2.6
	7	3	42.9	4	57.1	0	0	3	42.9	2	28.6	3	42.9	0	0	0	0
	70	24	34.3	46	65.7	22	31.4	26	37.1	5	7.1	5	7.1	0	0	0	0
	13	1	7.7	12	92.3	4	30.8	7	53.8	4	30.8	4	30.8	0	0	0	0
Total	128																
Average			28.5		71.5		22.8		44.6		22.6		26.8		0		0.7
Probable error			±8.7		±8.7		±4.5		±2.0		±3.1		±4.3		±0		±0.38
Dry sulfur and lead arsenate	33	9	27.3	24	72.7	18	54.5	9	27.3	3	9.1	3	9.1	0	0	3	9.1
	26	8	30.8	18	69.2	9	34.6	8	30.8	3	11.5	3	11.5	0	0	0	0
	42	16	38.1	26	61.9	19	45.2	11	26.2	2	4.8	3	7.1	0	0	0	0
	14	6	42.9	8	57.1	5	35.7	1	7.1	3	21.4	2	14.3	1	7.1	0	0
Total	115																
Average			34.8		65.2		42.5		22.9		11.7		10.5		1.8		2.3
Probable error			±1.9		±1.9		±2.7		±3.1		±2.55		±0.9		±1.0		±1.3

[8] All of the two inner of the unsprayed rows of trees, eight trees all together, are included in this tabulation as one tree.
[9] Three trees were picked together in this plot, from which these figures were taken.

It will be noticed that in the above results the relative control of the various pests was much like that in the Catchpole experiment, although poorer on the whole—as should be expected from two sprayings instead of three. This is particularly noticeable in the control of insects. In this experiment the application of arsenate of lead with the lime-sulfur solution and with the suspension of sulfur yielded results more nearly alike, as should be expected, than were obtained in the previous experiment. Better control of insects was secured in this experiment with the dust than with liquid spray, but poorer control of apple scab as in the experiment previously described.

The result of the counts of drops is liable to considerable error because of the small number of drops; but here again, in a general way, the figures affirm the statements previously made, although the dropped apples were naturally more infested than were the picked apples.

Commercial grading.— These apples were sorted by the grower, as in the previous case, and an account was kept of the different grades except on the unsprayed plat where altogether there was only a half barrel of very poor apples. The results of the commercial sorting are given in the following table:

TABLE 11. COMMERCIAL GRADING OF PICKED TOMPKINS KING APPLES FROM THE LAWSON ORCHARD

Treatment	Number of trees	Total yield (barrels)	No. 1 apples		No. 2 apples		No. 3 apples		Yield per tree (barrels)
			Barrels	Percentage	Barrels	Percentage	Barrels	Percentage	
Unsprayed	19	0 66	..	......	..	.....	.	...	0.04
Suspension sulfur	15	4.72	3 00	63 5	1.50	31.8	22	4 7	0 32
Lime-sulfur	13	8 06	5.50	68.2	2.00	24 8	.56	7.0	0.62
Dry sulfur	15	12.16	9.00	74 0	2.66	21 9	.50	4 1	0.81

In this experiment, also, the better insect control apparently more than made up for the poorer control of scab, so that the dusted apples graded better commercially than those sprayed with the liquid.

Experiments in the Northern Spy orchard

Although the third spray was omitted on this block because so few apples had set, it was thought worth while to make some record of the comparative results, since at the time of picking the Tompkins Kings there seemed to be nearly as many apples on the Northern Spy trees.

TABLE 12. DATA ON TIME AND METHODS OF APPLICATION, NORTHERN SPY APPLES, LAWSON ORCHARD, OWEGO, NEW YORK

Date of application	Number of trees	Material used, and strength	Quantity used	Time required: Horse Hrs.	Horse Min.	Man Hrs.	Man Min.	Machine Hrs.	Machine Min.	Cost: Labor	Material	Total cost	Cost per tree
			(Gals.)										
May 6.	41	Lime-sulfur 1–40; lead arsenate 3.5 pounds–100 gallons....	90	2	20	3	30	1	10	$0.93	$0 88	$1 81	$0 044
May 13.	41	Lime-sulfur 1–40; lead arsenate 3.5 pounds–100 gallons.....	80	2	00	3	00	1	00	0 80	0 78	1 58	0 039
Totals.	....	....	170	4	20	6	30	2	10	$1.73	$1 66	$3 39	$0 083
			(Lbs.)										
May 6 and 7.	40	Dry sulfur and arsenate of lead 4:1	80	1	04	1	04	0	32	$0 32	$4 22	$4.54	$0.114
May 15	40	Dry sulfur and arsenate of lead 4:1...	76	0	46	0	46	0	23	0 23	4 01	4 24	0 106
Totals.	...	....	156	1	50	1	50	0	55	$0 55	$8 23	$8 78	$0 220
			(Gals.)										
May 6 and 7.....	34	Paste sulfur 24; lead arsenate 3.5 pounds–100 gallons.	100	3	00	4	30	1	30	$1.20	$0 92	$2 12	$0 062
May 15 .	34	Paste sulfur 24; lead arsenate 3.5 pounds–100 gallons....	80	2	18	3	27	1	09	0 92	0 74	1 66	0 049
Totals .	..	....	180	5	18	7	57	2	39	$2 12	$1 66	$3.78	$0 111

In this block the apples on the unsprayed plat had remained longer on the trees, the fruit of this variety being less likely to be blown off from the trees than that of other varieties because of the long, flexible stems. The data on cost and methods of application for the Northern Spy apples are given in Table 12.

Through a misunderstanding all the apples on each plat in the Northern Spy orchard had been picked and placed together, so that counts from individual trees could not be made separately. The figures for the separate trees, therefore, cannot be given, nor the probable error determined on that basis. The probable error appears to be no greater, and appears to be even less in most cases, than in records from the Tompkins King apples, judging records for crates tabulated separately. Also, the number of apples examined in this case was nearly twice as large as in the case of the Tompkins King apples. It must be remembered in connection with these figures that the third application was not made; and this is noticeable in the very much higher percentage of apples injured by the late brood of codling moths, that is, the larvæ entering the sides of the apples. In fact, the sprays applied can scarcely be said to have had any effect on these insects. There was very little or no scab-infection weather after the third application, so that the results on scab control should be fairly comparable with those in the case of the Tompkins King apples.

The drops on these plats were so few as not to give any reliable data. On the lime-sulfur plat only seventy-nine apples were picked up at picking time, which number does not give a fair basis for comparison.

The number of apples counted and the number falling in each class, with percentages of each, are given in Table 13.

As stated above, the lack of the third spray is clearly apparent in these results in the large amount of injury done by codling-moth larvæ entering the sides of the apples and in the poor curculio control. It may safely be said that the figures on curculio do not fully represent the difference between the sprayed and the unsprayed plat; because as a rule the apples injured by curculio on the check plat frequently showed the effects of numerous punctures, so that they were almost wholly misshapen, while those on the sprayed plat recorded as affected by curculio usually had not more than a single puncture, or possibly two punctures, causing russeted patches to appear on the apples.

In the control of bud moth, leaf-rollers, and the green fruit worm, and the codling moth entering the calyx end of the apple, the results are clearly in accord with the experiments previously described. The dust mixture as applied was superior to the liquid sprays.

The apples sprayed with lime-sulfur solution in this experiment showed 39.8 per cent of scabby apples as compared with 25.8 per cent for those

TABLE 13. A CLASSIFICATION OF THE PICKED NORTHERN SPY APPLES FROM THE LAWSON ORCHARD, OWEGO, NEW YORK

Treatment	Total number of apples	Sound		Unsound		Apple scab		Bud moth and other spring caterpillars		Codling moth		Codling moth				Curculio	
												Side entrance		Calyx entrance			
		Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Per centage	Number	Percentage	Number	Percentage
Untreated	914	84	9 2	830	90 8	459	50 2	214	23 4	420	46 0	476	52 1	70	7 7	293	32 1
Suspension of sulfur and lead arsenate	912	267	29 3	645	70 7	211	23 1	147	16 1	357	39 1	411	45 1	30	3 3	44	4 8
Lime-sulfur and lead arsenate	420	93	22 1	327	77 9	167	39 8	79	18 8	, 176	41 9	257	61 2	12	2 9	20	4 8
Dry sulfur and lead arsenate	4,429	1,689	38.1	2,740	61 9	1,143	25 8	303	6 8	1,211	27 3	1,412	31 9	85	1 9	652	14 7

dusted. The error here in the average for the dusted plat does not appear very large, judging from the percentage of scabby apples in the lots tabulated separately. There may be a larger error in the average for the check plat, as a fewer number of apples were considered here.

In this experiment it is also noticeable that the percentage of sound apples was largest on the dusted plat, which seemed to be the tendency in the other dusted plats although not quite so marked as here.

GENERAL SUMMARY AND CONCLUSIONS

No attempt has been made to use the dust mixture as a dormant treatment, and it is rather improbable that it would prove effective against San José scale.

All previous reports from experiment stations of the efficacy of dusting for apple scab have been negative. The essential fungicidal agent in previous tests has been copper.

The use of finely ground sulfur as the fungicide in a dust mixture has given very encouraging results and warrants further trials on a more extensive scale.

The application of arsenate of lead in powdered form in the quantities applied is more effective against the common orchard insects that chew than is the same substance applied wet.

The cost of material and application of the dust mixture used this year is as great as, or greater than, the application of a wet spray.

The time required for dusting an orchard is much less than that required for spraying it.

The orchardist with additional acreage coming into bearing can probably afford to await the results of another year of experimentation before buying additional equipment.

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CONTENTS

CROP YIELDS AND PRICES, AND OUR FUTURE FOOD SUPPLY

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The questions, whether our soil is exhausted and how we are to be fed in the future, are constantly being discussed in newspapers and magazines. The wildest sorts of statements are being made Statistics are so persistently misquoted and misused that wrong impressions or absolute untruths are often accepted. The farmer is blamed for not selling enough food, and in the next breath is condemned for allowing any plant food to leave his farm. Many public-spirited citizens are planning all manner of solutions for existing conditions, sometimes with an entire misconception of what such conditions are. In the midst of all the excited discussion, it is well to stop long enough to examine the available facts and find out where we stand. There are two, and only two, sources of information on crop yields, the United States Census Reports and the reports by the Bureau of Statistics of the United States Department of Agriculture.

CROP YIELDS

Crop yields in the United States.— The crop yields for the United States as reported by the census are given in Table 1. Of the six major crops, three gave their highest yield at the last census period and three had given a better yield at some previous period.

TABLE 1. CROP YIELDS PER ACRE IN THE UNITED STATES, FROM THE CENSUS REPORTS

	1879	1889	1899	1909
Major crops				
Corn (bushels)	28.1	29.4	28.1	25.9
Wheat (bushels)	13.0	13.9	12.5	15.4
Oats (bushels)	25.3	28.6	31.9	28.6
Potatoes (bushels)	......	83.6	93.0	106.1
Hay and forage (tons)	1.15	1.26	1.28	1.35
Cotton (bales)	0.40	0.37	0.39	0.33
Minor crops				
Tobacco (pounds)	740	702	788	815
Barley (bushels)	22.0	24.3	26.8	22.5
Buckwheat (bushels)	13.9	14.5	13.9	16.9
Rye (bushels)	10.8	13.1	12.4	13.4
Rice (bushels)	22.7	28.7	26.3	35.8
Sweet potatoes and yams (bushels)	75.0	83.8	79.1	92.4
Hops (pounds)	567.2	780.1	884.9	911.1
Flax (bushels)	.....	7.8	9.5	9.4

TABLE I (*continued*)

	1879	1889	1899	1909
Minor crops (*continued*)				
Kafir corn and millo maize (bushels)			19.4	10.8
Dry edible beans (bushels)			11 2	14.0
Sugar beets (tons)			7.2	10.8
Sugar cane (tons)			10.9	13.1
Sorghum cane (tons)			6.5	3.7
Dry peas (bushels)			9.7	5.5
Peanuts (bushels)			23.2	22.3
Strawberries (quarts)			1,701	1,788
Blackberries and dewberries (quarts)			1,239	1,129
Raspberries and loganberries (quarts)			1,258	1,252
Cranberries (quarts)			1,552	2,075
Currants (quarts)			1,445	1,329
Gooseberries (quarts)			1,380	1,109
Broom corn (pounds)		412 7	509.3	242.1
Hemp (pounds)		1,030 4	732.4	978.6
Chicory (pounds)			7,004	12,136
Mint (pounds)			21 8	19.3

There are sixteen crops for which the yield per acre is reported for at least three census periods. For these crops we find the following instances of first rank in yield:

Year	Instances of first rank in yield
1879	1
1889	2
1899	4
1909	9

While these figures may not be absolutely conclusive, they appear to indicate that the crop yields are better than formerly.

Crop yields east of the Mississippi River.— When crop yields for the entire United States are compared, the land considered in 1909 is different from that farmed in 1879. During that period, large areas of arid land were brought into cultivation. The average yields on this new land are lower than those in the older States. Hence the yields of later years are lowered, not by the exhaustion of the soils in the older States, but by the addition of new land with low yields. It is therefore misleading to quote the decrease in yield per acre of corn and attribute this decrease to soil exhaustion in the older States.

The only fair way of making a comparison is to consider the same region for each census period. Table 2 shows a comparison for the most important crops in States east of the Mississippi River. In this region the best crops of corn, wheat, potatoes, and hay ever produced were in 1909. The best yields of oats and cotton were in the year 1899, with 1909 second.

TABLE 2. CROP YIELDS PER ACRE IN STATES EAST OF THE MISSISSIPPI RIVER, FROM THE CENSUS REPORTS

Crop	1879	1889	1899	1909
Corn (bushels)	25.6	25.6	27.2	28 0
Wheat (bushels)	14 1	14.3	11.9	15 8
Oats (bushels)	24 2	27.5	32.6	29 5
Potatoes (bushels)	.	81 6	90 7	108 4
Hay and forage (tons)	1 08	1 24	1.17	1.29
Cotton (bales)	0 37	0 35	0 39	0 39

A still more accurate comparison is shown in Table 3. The States east of the Mississippi River are here grouped in five divisions and those west of the Mississippi in four divisions. Considering the first five divisions and the six most important crops, we have the following instances of first rank in yield:

Year	Instances of first rank in yield
1879	0
1889	3
1899	5
1909	19

A better method of comparing yields is on the basis of the reports by the Bureau of Statistics. The census figures are more accurate, but the census is taken only once in ten years. The crops vary from year to year, chiefly because of variation in rainfall. The census figures are therefore dependent on whether the year is one of good or poor crops.

The estimates published by the Bureau of Statistics are available for every year since 1866. At the present time these estimates are based on reports from every county in the United States that is of any agricultural importance. There are approximately 32,000 persons who send

TABLE 3. CROP YIELDS PER ACRE BY GROUPS OF STATES, FROM THE CENSUS REPORTS

		Corn (bushels)	Wheat (bushels)	Oats (bushels)	Hay and forage (tons)	Cotton (bales)	Potatoes (bushels)
States east of the Mississippi River							
New England . . Me., N. H., Vt., Mass., R. I., Conn	1879	34.5	15.5	32.7	0.96	.	109
	1889	38.6	19.1	30.7	1.09	.	85
	1899	39.4	18.0	35.9	1.13		130
	1909	45.3	23.5	32.9	1.23	...	177
Middle Atlantic.... N. Y., N. J., Pa.	1879	33.1	14.1	28.5	1.10	. ..	95
	1889	32.8	16.7	27.4	1.29	....	70
	1899	34.0	14.9	30.9	1.19	. ...	95
	1909	32.2	18.6	25.5	1.32	.....	107
East North Central. Ohio, Ind., Ill., Mich., Wis.	1879	34.6	16.8	31.8	1.17	......	....
	1889	34.3	15.7	34.5	1.30	......	91
	1899	38.3	12.9	37.4	1.22	......	85
	1909	38.6	17.2	33.3	1.38	......	101
South Atlantic.... Del., Md., D. C., Va., W. Va., N. C., S. C., Ga., Fla.	1879	13.3	8.8	9.9	0.84	0.35	....
	1889	13.7	10.3	10.8	1.09	0.35	70
	1899	14.1	9.5	11.7	1.02—	0.39	77
	1909	15.8	11.9	15.5	1.02+	0.45	92
East South Central Ky., Tenn., Ala., Miss.	1879	19.1	7.7	10.3	0.82	0.39—	....
	1889	20.7	10.6	12.1	1.06	0.35	81
	1899	18.4	9.0	11.1	1.03+	0.39+	63
	1909	18.6	11.7	13.4	1.03	0.32	82
States west of the Mississippi River							
West North Central Minn., Iowa, Mo., N. Dak., S. Dak., Nebr., Kan.	1879	37.4	10.6	28.9	1.32	.	....
	1889	36.4	13.2	30.9	1.26	. ..	90
	1899	31.4	12.2	32.0	1.34	......	95
	1909	27.7	14.9	27.5	1.33	....	92
West South Central Ark., Va., Okla., Tex.	1879	14.0	6.6	17.0	0.83	0.47	....
	1889	20.9	10.6	20.2	1.35	0.41	73
	1899	21.9	11.9	25.8	1.48	0.39	67
	1909	15.7	11.0	21.4	1.03	0.27	63
Mountain......... Mont., Idaho, Wyo., Colo., N. Mex., Ariz., Utah, Nev.	1879	16.6	18.8	28.9	1.13	..... .	....
	1889	14.4	20.0	27.8	1.36	......	69
	1899	16.5	19.2	30.4	1.59	......	113
	1909	15.8	23.1	34.9	1.73	......	143
Pacific.......... Wash., Ore., Cal.	1879	27.1	16.3	30.5	1.45	......	....
	1889	30.2	15.0	28.4	1.49	.....	95
	1899	25.2	15.6	31.4	1.44	... .	129
	1909	24.0	17.7	35.3	1.73	. .. .	131

in crop reports. The yields per acre of the important crops are estimated with a fair degree of accuracy. The yield per acre of the corn crop of 1909 was 2 per cent less than that indicated by the census report; that of cotton was 3 per cent less. The estimated yield per acre of wheat was 2 per cent too high, for oats 6 per cent, and for potatoes 1 per cent too high.

Table 4 shows the comparative yields of corn, wheat, oats, barley, rye, buckwheat, potatoes, and hay, for every year since 1866. Each crop was compared with its 1866 yield as 100 per cent. These percentages were then averaged in order to get the percentage yield for each year. If one crop had more acreage than another, it is given proportionately more

TABLE 4. COMPARATIVE CROP YIELDS, FROM REPORTS OF THE BUREAU OF STATISTICS. CORN, WHEAT, OATS, BARLEY, RYE, BUCKWHEAT, POTATOES, HAY. THE YIELD OF 1866 CONSIDERED AS 100 PER CENT

Year	United States (percentage of 1866 crop)	States east of the Mississippi River (percentage of 1866 crop)
1866	100	100
1867	100	99
1868	104	102
1869	108	102
1870	109	109
1871	109	107
1872	112	111
1873	101	93
1874	94	95
1875	109	106
1876	100	99
1877	112	110
1878	115	112
1879	116	118
1880	110	114
1881	86	86
1882	104	104
1883	100	100
1884	107	99
1885	99	94
1886	96	96
1887	91	89
1888	101	107
1889	108	102
1890	89	88
1891	112	107
1892	99	96
1893	97	96
1894	93	102
1895	105	98

TABLE 4 (*continued*)

Year	United States (percentage of 1866 crop)	States east of the Mississippi River (percentage of 1866 crop)
1896	109	104
1897	107	107
1898	116	117
1899	108	103
1900	105	101
1901	96	97
1902	119	116
1903	111	105
1904	114	111
1905	123	121
1906	123	120
1907	109	113
1908	112	113
1909	115	115
1910	113	121
1911	97	110
1912	126	120

weight in determining the average. The figures are what is known as a weighted average.[1] This is the fairest possible way of comparing the yield of different acres, since it gives every acre equal weight.

Figure 21 shows the comparative yields for States east of the Mississippi River. This curve shows a period of general low production during the eighties and the early nineties. During that period prices were low and farmers were having hard times. Since 1896 the yields in these States have only once dropped below the 1866 crop; that was in the very dry year

[1] The method of calculating the comparative crop yields, or the crop index, is best shown by an example:

	Acres grown in 1912	Comparative yield per acre (1866 yield as 100 per cent)	Acres multiplied by percentage yield
Corn	107,083,000	115	123,145,450
Wheat	45,814,000	161	73,760,540
Oats	37,917,000	124	47,017,080
Barley	7,530,000	130	9,789,000
Rye	2,117,000	124	2,625,080
Buckwheat	841,000	105	883,050
Potatoes	3,711,000	113	4,193,430
Hay	49,530,000	120	59,436,000
Total	254,543,000		320,849,630

$$\text{Percentage yield, or crop index} = \frac{320{,}849{,}630}{254{,}543{,}000} = 126 \text{ per cent.}$$

of 1901. Never before have the eastern States shown such high yields as in the last eight years considered. In four of these years the crops have been better than ever before produced. In every year the crops have been good.

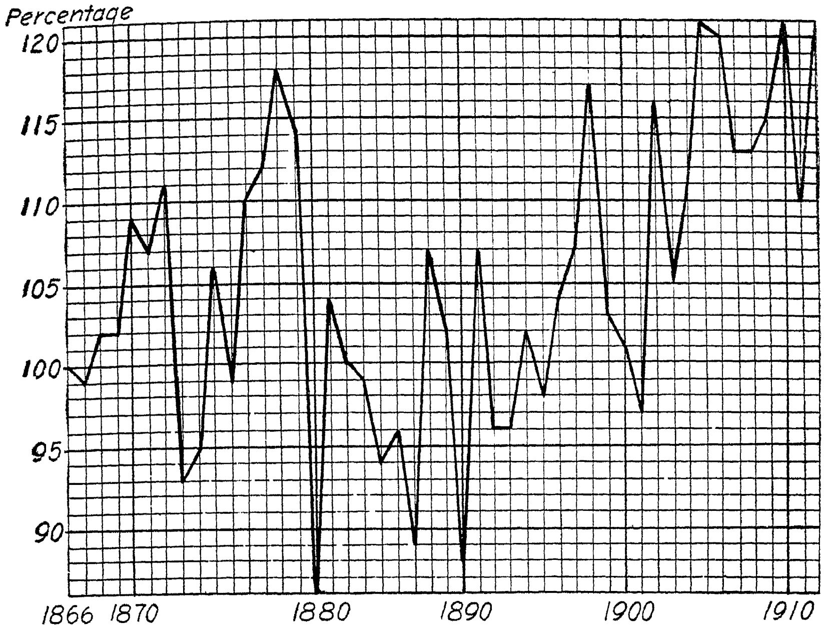

FIG. 21.—*Comparative crop yields in States east of the Mississippi River. Yields of 1866 considered as 100 per cent*

Crop yields in New York.— The crop yields in New York in 1909 were much the best ever reported by the census. Corn, wheat, potatoes, hay, buckwheat, rye, and beans gave the best yields ever recorded. Oats and barley were not so good as in previous years. (Table 5.)

TABLE 5. CROP YIELDS PER ACRE IN NEW YORK, FROM THE CENSUS REPORTS

	1879	1889	1899	1909
Major crops				
Corn (bushels)	33.0	30.6	30.4	35.4
Wheat (bushels)	15.7	18 0	18 7	23.0
Oats (bushels)	29.8	27.4	30.7	26.7
Potatoes (bushels)	98 8	68 9	96.2	123.2
All hay and forage (tons)	1.13	1 27	1.23	1.40
Timothy alone	....	....	....	1.07
Timothy and clover mixed	....	....	....	1.10
Clover alone	....	....	1.11	1.32
Alfalfa	....	....	2.33	2.46
Millet, or Hungarian grass	....	....	1.76	1.81

TABLE 5 (*continued*)

	1879	1889	1899	1909
Minor crops				
Buckwheat (bushels) . .	15 3	16 7	13 2	19.9
Barley (bushels) .	21 8	23 5	26.4	24 0
Rye (bushels)	10 8	12 9	13.7	15 4
Emmer and spelt (bushels) .		. .	. . . . . .	24 5
Beans, dry (bushels) .			10 5	14.5
Peas, dry (bushels) .			17 1	17.8
Hops (pounds) . . .	553 6	547 1	629.5	721.7
Strawberries (quarts) .			1,894	2,499
Blackberries and dewberries (quarts)		. .	1,537	1,286
Raspberries and loganberries (quarts)		.	1,420	1,334
Currants (quarts) . . .			1,767	1,557
Tobacco (pounds)	1,313	1,080	1,234	1,301
Sorghum cane (tons) . .	.		7.5	4.48
Root forage (tons)	. . . . .	. . .	. . . . . .	10 06

The same comparison, based on figures of the Bureau of Statistics, is shown in tables 6 and 7 and in Fig. 22. For nearly a generation, during

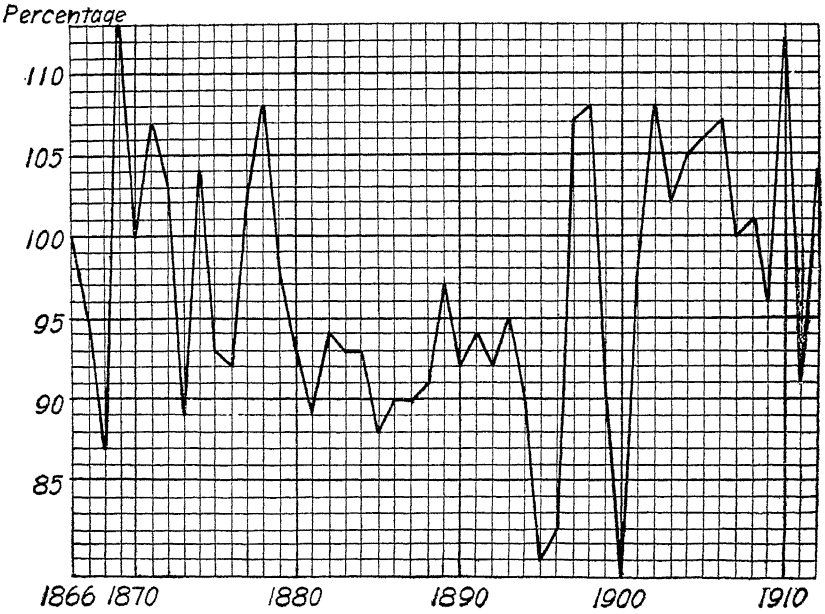

FIG. 22.—*Comparative crop yields in New York. Yields of 1866 considered as 100 per cent*

the agricultural depression when farming did not pay well, crop yields were low. During the past sixteen years they have been much better.

TABLE 6. Ten-years Average Crop Yields in New York, from Reports of the Bureau of Statistics

	1866–1875	1876–1885	1886–1895	1896–1905	1906–1912 (seven-years average)
Corn (bushels)	31 6	30 4	31.1	30.3	36 0
Wheat (bushels)	14 1	15 5	15 4	17.5	19.3
Oats (bushels)	32.3	30 5	26 2	31.4	30 9
Barley (bushels)	22.1	23 0	21 0	24.1	25 9
Rye (bushels)	14 2	13.0	13.6	16 0	17.0
Buckwheat (bushels)	20 0	14 8	15 8	17.7	21 4
Potatoes (bushels)	100.7	78 8	76 3	78.9	98 1
Hay (tons)	1.21	1 16	1 12	1.20	1 20

TABLE 7. Comparative Crop Yields in New York, from Reports of the Bureau of Statistics. Corn, Wheat, Oats, Barley, Rye, Buckwheat, Potatoes, Hay. The Yield of 1866 Considered as 100 per Cent

Year	Comparative yields
1866	100
1867	95
1868	87
1869	113
1870	100
1871	107
1872	103
1873	89
1874	104
1875	93
1876	92
1877	102
1878	108
1879	98
1880	93
1881	89
1882	94
1883	93
1884	93
1885	88
1886	90
1887	90
1888	91
1889	97
1890	92
1891	94
1892	92
1893	95
1894	90
1895	80

TABLE 7 (*continued*)

Year	Comparative yields
1896	82
1897	107
1898	108
1899	91
1900	79
1901	97
1902	108
1903	102
1904	105
1905	106
1906	107
1907	100
1908	101
1909	96
1910	112
1911	91
1912	104

Why are crop yields increasing?— The writer does not believe that changes in crop yields can be taken as a measure of soil fertility. If so, then we must conclude that the longer land is farmed the richer it gets, because the Atlantic Coast States show the largest increase in crop yields. The striking increase is due to the better returns that crops now bring. Every farmer knows many ways of increasing his crops. Whenever prices rise, more fertilizers and better methods are used. In the States east of the Mississippi River, in 1899, the average expenditure for fertilizer was 36 cents per acre of crops. In 1909 it was 78 cents.

Probably much more important than the expenditure for fertilizer is the increased attention that is being given to the care and use of farm manure. Methods of tillage also have been improved. Much land has been drained, so that wet spots which once lowered the average yield are now raising it.

It is certainly very unsafe to draw conclusions from crop yields as to whether our soils are running out. The yields are increasing, whatever the cause.

Crop possibilities.— There are many ways in which it is possible to increase crops. There is much good land that is not now being used, but that will be used as soon as prices make it worth while. The use of more fertilizers, the better use of manure, and other methods of more careful farming are rapidly coming in as prices make it worth while.

There are millions of acres of good farm land in swamps, which we will farm as soon as we are convinced that it will pay to drain them. Shaler

estimates that there are 3,000,000 acres of reclaimable seacoast marsh-land along the Atlantic coast of the United States.

There are other millions of acres on farms, made up of smaller areas from fractions of acres to large marshes, which are gradually being reclaimed. On the vast majority of American farms there are areas of land that can be brought into cultivation when prices warrant the work. In total, this is far more important than reclaiming the large swamps.

The writer made a study of 13 farms, containing 1060 acres, near Ithaca. On these farms nearly 210 acres of land are still in woods or stumps that will make excellent farm land when cleared. This land is just as good as any of the present cleared land. This is in addition to woodland that must be kept permanently in woods. During the past three years, on these farms, 17 acres of previously waste wet land and 63 acres of wood-land have been turned into pasture, and 44 acres of pasture land and 7 acres of previously waste land have been taken for crops. This example is typical of the State. Probably more brush lines along fences and wet places have been reclaimed in New York in the last five years than in the preceding twenty-five years. Prices in New York are usually not high enough to justify one in clearing land all at once, but woodland and brush-land can be turned into pasture and be ready to clear cheaply in about twenty years, after the stumps have partly rotted. In this way the saving in cost of clearing may equal the value as pasture, and the two usually pay better than clearing at once by expensive methods.

The above conditions are typical not only of New York, but also of most of the farms in the eastern States. At the same time there is much land that is not worth farming that should be reforested, but not much of this is in crops at the present time. We still have much undeveloped land, but not of the kind that was opened in the Central West. We must now work for our new land and must be willing to pay the corresponding prices for the products.

PRICES OF FARM PRODUCTS

Comparative prices for 73 years.— The wholesale prices in cities, of corn, wheat, cotton, potatoes, oats, hogs, beeves, sheep, butter, and eggs, from 1840 to 1912 inclusive, are given in Table 8. Details as to where the figures were obtained are given in the footnotes to the table. The average prices for the 73 years and the average prices for the last 8 years considered were as shown in Table 9.

The table includes five crops and five animal products. The lowest prices ever reported for each class of products was in 1896. The general average for that year was 59 per cent of the average prices for 73 years.

TABLE 8 AVERAGE WHOLESALE PRICES IN CITIES, 1840 TO 1912

Year	Corn[1] New York (per bushel) (cents)	Winter wheat[2] New York (per bushel)	Cotton[3] (Upland Middling) New York (per pound) (cents)	Potatoes[4] (per bushel) (cents)	Oats[5] New York (per bushel) (cents)	Hogs[6] (per 100 pounds)	Beeves[7] (good to prime) (per 100 pounds)	Sheep[8] (good to choice) Cincinnati (per pound) (cents)	Butter[9] (per pound) (cents)	Eggs[10] (per dozen) (cents)	Comparative prices[11] (average for 73 years equals 100 per cent)
1840.	57	$1 12	8 9	.	36	$4 41	$3.71	.....	16 0	..	75
1841.	60	1 18	9 5	...	45	4 75	3.82	......	17 1	. .	81
1842.	61	1 17	7.9	.	40	4 14	3 24	......	17 6	.. .	75
1843.	54	1 04	7 3	...	30	4 33	3 28	1 1	14 8	..	63
1844.	50	0.97	7.7	. ..	32	4.50	3.23	1.6	17 6	.. ..	63
1845.	51	0 99	5.6	....	37	4 00	3 42	......	16 0	....	67
1846.	65	1 12	7 9	. .	41	4.53	3.64	......	16.5	.....	77
1847.	84	1.38	11 2	.....	46	5 34	4.13	1.2	18.4	..	86
1848.	63	1 33	8 0	.....	43	5 14	4.10	1.5	17 3	....	78
1849.	61	1.23	7.6	.....	36	4.88	4.72	......	17.8	.. .	80
1850.	61	1.30	12 3	.....	43	4 06	4.41	......	16.8	.....	84
1851.	63	1.09	12.1	73	44	4.83	4 45	2.3	16.8	.....	85
1852.	66	1 11	9 5	64	45	5 44	4 90	1.8	21.3	.....	85
1853.	71	1 36	11.0	47	48	5 97	5 46	3 1	21 3	.....	93
1854.	77	2.00	11.0	98	53	5 34	5.43	3.6	19.9	.. ..	109
1855.	94	2 30	10 4	93	59	5 66	6 09	3.9	23 1	.....	119
1856.	69	1 76	10 3	59	45	6 53	5 95	3.0	21.4	.....	99
1857.	73	1.58	13 5	100	53	6 88	6 23	2.8	23.1	16.9	107
1858.	68	1.17	12 2	79	47	5 23	5 04	2.0	19.6	16 0	88
1859.	86	1.46	12.1	58	51	5.59	5.78	2.8	20.8	20.9	98
1860.	73	1 38	11.0	49	42	6 28	5.46	3 6	18 8	17 4	91
1861.	59	1 28	13 0	48	34	4 67	5 08	3 4	15 4	14 4	81
1862.	59	1 31	31 3	45	45	4 03	5.11	3 4	18 5	15 8	96
1863.	83	1 52	67 2	50	74	5 16	5 85	4 5	23 3	20.8	142
1864.	144	1.99	101.5	88	92	9 54	8.20	5 6	38 6	26.3	210
1865.	124	2.05	83 4	76	83	12 69	9 94	6.8	39 3	29 4	205
1866.	88	2.30	43 2	71	54	10 59	9 21	5.6	44 4	28 4	162
1867.	117	2 84	31 6	71	70	7.36	9 03	5 1	32 6	27 4	155
1868.	120	2.46	24 9	102	81	8.91	9.38	4.7	43.3	32 1	164
1869.	100	1.18	29 0	70	74	10.27	8.93	3 9	41.4	31.3	145
1870.	99	1 31	24 0	76	60	9 50	9.14	4.1	34.6	31.3	137
1871.	77	1.60	17 0	102	62	5 13	7 63	3.5	32 3	25 0	121
1872.	70	1.62	20.5	49	49	4.31	6 89	4 9	29.4	26 3	111
1873.	63	1.76	18 2	83	48	4 46	6 63	4 8	30 0	28.0	115
1874	85	1.46	17.0	87	59	5.60	6.51	4.8	33 0	28 0	121
1875.	82	1.33	15.0	70	63	7.48	6 84	4.9	30.3	25.8	119
1876.	63	1 35	13.0	47	44	6.94	5 81	4 8	30 9	22.9	103
1877.	58	1 63	11.7	88	42	5.55	6.07	4 5	27.1	21.1	104
1878.	53	1 25	11.3	49	33	3.84	5.23	3 9	27 1	16 9	85
1879.	47	1.17	10.8	78	34	3 44	5 08	4 0	22.4	18.0	85
1880.	55	1.30	12 0	47	42	4.61	4 88	4.7	29 3	16.9	91
1881.	62	1.31	11.3	69	45	5.93	6 20	4 9	28 6	22 2	103
1882	76	1.32	12 2	93	54	6 00	7.18	5 0	33 6	22 9	116
1883.	64	1.16	10.6	68	44	6.17	6 53	4 7	28 5	23.4	102
1884.	61	1.00	10 6	49	36	5 54	6 63	4.8	28.0	22.9	95
1885.	52	0 94	10.5	46	37	4 24	5.78	4.1	23.8	19 3	84
1886.	47	0 89	9.4	64	39	4.09	5 76	4.6	27 3	19.3	87
1887.	49	0.88	10 3	61	37	4 89	5 19	4 5	24 6	21 0	87
1888.	59	0 94	10 3	78	36	5.65	5 67	4.7	25 1	20 8	94
1889.	43	0 92	10.7	57	29	4.68	4.65	4.8	23 9	18.7	83
1890.	44	0.92	11.5	91	34	3.95	4.96	4 8	21.8	19.0	88
1891	67	1 06	9.0	93	46	4.42	5.55	4.7	23.8	20.9	97
1892.	55	0.79	7.6	45	36	5.16	4.50	......	23 5	19 1	77
1893.	46	0.69	8.2	67	34	6 55	4.84	......	25 2	21.1	84
1894.	57	0.58	7.7	61	35	4 97	4.52	......	20.9	16.4	76
1895.	40	0.70	6.3	43	25	4.28	4.93	.....	18 8	16.6	66
1896.	29	0.78	7.9	20	23	3.36	4 27	3 1	16.7	15.4	59
1897.	31	0.97	7.2	33	23	3.59	4.77	3.8	16.8	15.5	65
1898.	37	0.96	6.0	51	30	3.81	4 88	3.9	17.5	16.3	71
1899.	41	0.80	6.6	42	31	4 04	5.39	3.8	19.7	19.3	73

TABLE 8 *(continued)*

Year	Corn[1] New York (per bushel) (cents)	Winter wheat[2] New York (per bushel)	Cotton[3] (Upland Middling) New York (per pound) (cents)	Potatoes[4] (per bushel) (cents)	Oats[5] New York (per bushel) (cents)	Hogs[6] (per 100 pounds)	Beeves[7] (good to prime) (per 100 pounds)	Sheep[8] (good to choice) Cincinnati (per pound) (cents)	Butter[9] (per pound) (cents)	Eggs[10] (per dozen) (cents)	Comparative prices[11] (average for 73 years equals 100 per cent)
1900.	46	$0 81	9 6	37	27	$5 08	$5 39	3 7	21 2	17 1	75
1901	56	0 80	8 6	56	37	5 96	5 59	3 3	20 1	18 9	82
1902.	68	0 84	8 9	60	45	6 97	6 56	3 8	23 2	22 6	95
1903.	56	0 86	11 2	52	41	6 06	5 06	3 8	21 5	23 2	88
1904.	56	1.11	12.1	73	42	5 16	5.19	3 7	19 7	24 8	92
1905.	57	1 03	9.6	40	35	5 29	5 22	4 6	23 4	26 0	88
1906.	54	0.87	11 0	55	38	6 24	5 36	4 6	23 3	23 9	91
1907	62	0 96	11 9	49	49	6 08	5 81	4 7	26 7	26 5	98
1908.	71	1.05	10 5	71	54	5.80	6 00	4 1	24 5	26 5	102
1909.	76	1.25	12.1	69	51	7 57	6.45	4.4	26 5	30.6	111
1910.	65	1.12	15 1	43	47	8 94	7 02	4.7	29 1	32 8	112
1911.	66	0 97	13.0	77	46	6 75	6 73	3 4	25 7	29 9	104
1912.	76	1 09	11 5	91	57	7 60	8 40	3 8	30 0	33 1	119
73-yr av	66	$1 25	15 4	65	45	$5 71	$5 74	4 0	24 4	22 6	. . .

1 The prices of corn for 1840 to 1891 are from "Wholesale Prices, Wages, and Transportation," 52d Congress, Second session, Senate Report 1394, part 2, page 7. The price for each year is the average of the average prices for January, April, July, and October The prices for 1892 to 1912 are for "No 2 corn," U. S. Dept. Agr., Yearbook 1896, page 579; 1900, page 760, 1905, page 662; 1909, page 441; 1912, page 563. The price for each year from 1892 to 1896 is the average of the average prices for August, September, October, November, and December. The prices for later years are for all months In all cases in which monthly prices are given, the average of the high and the low is taken as the price for that month. The yearly average is the average of the monthly averages. Most of the corn sold is graded as No. 2. The months given are typical, so that the prices are comparable

2 Prices of wheat are from the references given in footnote 1 and are calculated by the method there given. Winter wheat, 1840 to 1891, Senate Report, page 63. 1892 to 1912 is "No. 2 red winter," U. S. Dept. Agr., Yearbook 1896, page 580; 1900, page 771; 1905, page 673, 1909, page 453; 1912, page 575.

3 Cotton prices are from U. S. Dept. Agr., Bureau of Statistics, Bulletin 9. U. S. Dept. Labor, Bulletin 114, page 93.

4 Potato prices are for Boston from 1851 to 1891, from Senate Report mentioned in footnote 1, page 118. Prices 1892 to 1912 are for "fair to fancy" potatoes in Chicago, from U. S. Dept. Labor, Bulletin 114, page 108. Potatoes average a little higher in Chicago than in New York.

5 Prices of oats are from the reference given in footnote 1 and are calculated by the method there given. Senate Report, page 32. Prices 1892 to 1912 are for "No. 2 mixed," U. S. Dept. Agr., Yearbook 1896, page 581; 1900, page 779; 1905, page 680; 1909, page 465; 1912, page 588. As in the case of corn and wheat, most of the product sold is graded as No. 2, hence the figures for different years are comparable.

6 Prices of hogs are for "good to prime" in New York, 1840 to 1870, Senate Report, page 28. Prices 1871 to 1889 are for Chicago, Senate Report, page 29. Prices 1890 to 1912 are for "heavy" hogs in Chicago, U. S. Dept. Labor, Bulletin 114, page 94. The prices in New York are a little higher than in Chicago, hence the figures before 1871 are a little high. The prices are given for both cities for 1871 to 1891. The New York average for these twenty-one years is nearly 10 per cent higher than in Chicago. The prices for Chicago from both references are given for 1890 and 1891. In these two years there is a difference of only one per cent (see footnote 11).

7 Prices of beeves are for "good to prime" in New York for 1840 to 1891, Senate Report, page 25. For 1892 to 1912 the prices are for "good to choice" in Chicago, U. S. Dept. Labor, Bulletin 114, page 93. The prices in New York are a little higher than those in Chicago. The prices are available for both cities in 1890 and 1891. In these two years the New York prices were 14 per cent higher than the Chicago prices. The prices in the table before 1892 are a little too high for exact comparison with the later prices (see footnote 11).

8 Sheep prices 1853 to 1891 are for "good to choice" in Cincinnati, Senate Report, page 31. Prices 1896 to 1912 are for "good to extra," U. S. Dept. Agr., Yearbook 1900, page 830; 1905, page 747; 1909, page 580; 1912, page 694.

9 Prices of butter 1840 to 1890 are for Boston from "Monthly Summary of Commerce and Finance of the United States," May, 1900, Bureau of Statistics of the Treasury Department, page 3153. Prices for 1891 to 1912 are for "State dairy, tubs, finest" in New York, U. S. Dept. Labor, Bulletin 114, page 98. The prices are given for both cities for 1890 to 1898. For these nine years the prices were almost the same in both cities. They average less than 3 per cent higher in Boston. The figures are therefore comparable.

10 Prices of eggs 1857 to 1895 are for Boston from "Monthly Summary of Commerce and Finance of the United States," May, 1900, Bureau of Statistics of the Treasury Department, page 3155. Prices for 1896 to 1901 are for "best fresh" in New York, U. S. Dept. Agr., Yearbook 1900, page 835; 1905, page 755; 1909, page 588; 1912, page 689. The prices are given for both cities for 1896 to 1898. For these three years the prices are nearly alike. In one year Boston was higher and in two years New York was higher. The prices therefore appear to be comparable.

11 The errors due to the change of cities in the case of beef and hogs would apparently make a difference of 2 per cent in the comparative price of all products. The opposite change in the price of potatoes would partly offset this. The percentages representing comparative prices from 1840 to 1891 are probably 2 per cent too high.

TABLE 9. AVERAGE PRICES OF PRODUCTS FOR GIVEN PERIODS

	Average for 73 years	Average 1905 to 1912
Corn in New York (per bushel)	$0.66	$0 66
Winter wheat in New York (per bushel)	1.25	1.04
Cotton in New York (per pound)	0.154	0.118
Potatoes (per bushel)	0.65	0.62
Oats in New York (per bushel)	0.45	0.47
Hogs (per hundred)	5.71	6.78
Beeves (per hundred)	5.74	6 37
Sheep (per hundred)	4.00	4.29
Butter (per pound)	0.244	0.262
Eggs (per dozen)	0.226	0.287

The prices for the crops for the last 8 years considered are no higher than the average for the 73 years. The animal products are higher. This is primarily due to very low prices of animal products before 1870, when range was free. Since 1896 grains have been rising in price faster than meat.

The comparative prices for 73 years are shown also in Fig. 23. The average price of each product was considered as 100 per cent. The per-

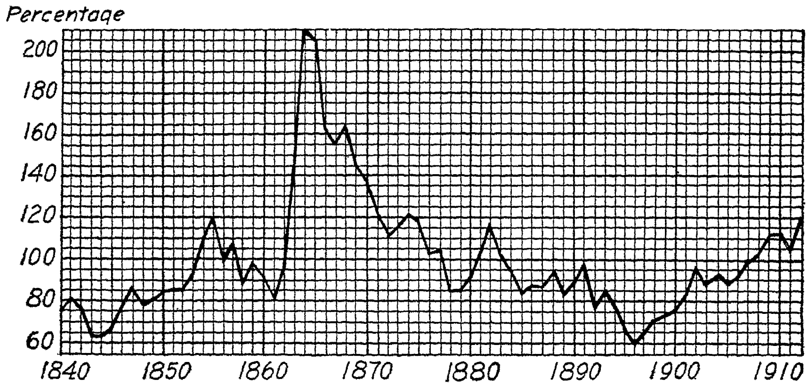

FIG. 23.—*Average wholesale prices in cities of five important farm crops and five important animal products. The average for 73 years equals 100 per cent. Present prices are only a little higher than the 73-years average*

centages for each product for each year were then calculated. The average of the percentages for a given year represents the comparative price for that year.

Prices of farm products on New York farms.— The average prices of some of the important products on New York farms on December 1 are given in Table 10. Of late years wheat has been lower than the average for forty-seven years. Other crops are generally higher. The period of low prices resulted in the low yields of the same period, as shown in Fig. 22.

TABLE 10. AVERAGE VALUES ON NEW YORK FARMS ON DECEMBER 1[1]

Year	Corn (per bushel) (cents)	Wheat (per bushel)	Oats (per bushel) (cents)	Barley (per bushel) (cents)	Rye (per bushel) (cents)	Buck-wheat (per bushel) (cents)	Pota-toes (per bushel) (cents)	Hay (per ton)
1866 ...	81	$1 86	42	74	84	64	48	$11 25
1867	95	1 89	54	105	107	74	64	12 51
1868 ...	83	1 55	55	132	102	75	57	11 16
1869.....	82	1 09	44	78	82	68	40	10 03
1870.....	78	1 27	52	76	87	73	58	15 45
1871.....	74	1 36	46	70	79	70	43	17 46
1872.....	62	1.46	39	72	79	74	56	16.47
1873.....	64	1.47	40	101	79	71	50	16.57
1874.....	84	1.14	51	106	83	72	51	11.81
1875.....	65	1.14	38	78	75	58	31	12.21
1876.....	62	1.20	38	76	75	68	73	10.27
1877.....	58	1.19	34	68	70	72	41	9.34
1878.....	50	1.02	29	70	58	50	81	7.40
1879....	61	1.40	40	72	75	54	36	9 79
1880.....	57	1.17	44	83	83	53	42	15 90
1881....	77	1.37	48	93	93	82	87	14 55
1882.....	77	1 10	45	80	76	75	61	12.25
1883....	73	1 11	40	75	72	86	39	10 50
1884....	60	0.85	35	66	63	56	39	12 50
1885....	58	0 96	36	71	67	53	45	12 75
1886.....	56	0.84	35	61	59	52	41	10 75
1887....	57	0.82	37	68	61	53	62	10.76
1888.....	58	1 10	37	70	63	62	38	11 25
1889.....	49	0 90	32	56	55	47	47	9.00
1890.....	65	1.00	50	78	73	58	78	7.75
1891.....	66	1 00	38	65	88	56	37	11.00
1892.....	60	0.85	39	75	65	50	65	11.00
1893.....	55	0.76	30	60	63	60	55	11 33
1894.....	61	0 62	39	56	54	54	48	9 66
1895.....	45	0.68	28	81	48	44	23	13 70
1896.....	38	0.88	26	39	44	37	31	12 04
1897.....	40	0.90	27	42	48	40	67	8.25
1898.....	43	0 72	31	48	50	45	42	5.75
1899.....	45	0 80	33	50	56	59	40	10.45
1900.....	47	0 77	32	51	56	57	45	14.05
1901.....	72	0.82	48	56	62	57	71	10 58
1902.....	67	0.79	36	55	58	59	59	10.53
1903.....	60	0.81	41	55	61	59	56	10.96
1904.....	64	1 09	38	57	73	61	54	10.44
1905.....	61	0.86	37	54	67	59	70	10.38
1906.....	59	0.82	40	55	65	61	49	12.10
1907.....	71	0.99	57	80	81	70	57	15.50
1908.....	80	0.99	56	70	81	76	75	12.25
1909.....	74	1.11	49	69	80	69	50	14.20
1910.....	63	0.96	42	70	74	65	48	13.70
1911.....	77	0.95	51	97	89	73	90	17.90
1912.....	70	0.99	42	68	76	64	58	14.90
Average for 47 years	64	$1.05	40	71	71	62	53	$11.92

[1] U. S. Dept. Agr., Bureau of Statistics. Bulletins 56–63, and Yearbook 1912.

Reasons for former low prices.— During the eighties and the early nineties there was a period of such serious overproduction of farm products that farmers received almost nothing for their work. The Yearbook of the Department of Agriculture gave the average farm price of corn in 1896 as 21½ cents per bushel of shelled corn. The average price in Nebraska in that year was 13 cents and in 1897 it was 17 cents.[2] The corn from a farm that the writer helped to operate, in eastern Nebraska, sold in 1896 for 8 cents per bushel of shelled corn, so that the above prices appear to be sufficiently high.

If efficient methods of farming are used, an acre of corn in the Corn Belt can be grown, harvested, and marketed with 20 to 25 hours of man labor and 40 to 50 hours of horse labor. The Yearbook reports the average yield of corn in Nebraska in 1896 as 37.5 bushels of shelled corn per acre. At 13 cents a bushel this was worth $4.88. This is the amount of money that the farmer received for two days work of himself and team, use of an acre of land, use of machinery, use of corncrib, and to pay the corn-shelling bill. This amount of money left the farmer less than no pay for his own labor. He paid for the privilege of working.

The prices of farm products in 1896 were the lowest for the past 73 years. Yet it is that year, 1896, with which present prices are almost invariably compared in order to show how high prices now are. Why not take 1846, 1856, 1866, 1876, 1886? Or, better yet, why not use a long enough period to tell whether we are on a "hill" of high prices or whether we have just passed through a "valley" of low prices?

The average farm price of corn in the United States for the ten years 1891 to 1900 was 33 cents a bushel. The average value of the crop per acre was $7.99. For the same ten years, the average farm price of wheat was 63 cents and the average value of the crop per acre was $8.44.

As a matter of fact, the last twenty years of the last century were a period the like of which we never had before and can never see again. The great open prairies were then skimmed. Following the Civil War, a large number of persons went into farming — probably too many for the old conditions, vastly too many for the new. New kinds of farm machinery came into general use in the eighties that doubled the farmer's efficiency. For ages, nature had been enriching the lands of the great Central Grass Belt. These lands had little value, so that land rent was almost nothing. They were exceedingly fertile, so that plant-food was free. Free land, free plant-food, too many farmers, new machinery — a combination of conditions that never before existed and can never come again! Those were the days when the Nebraska farmer burned corn because it was cheaper than coal. It is no wonder that our agricultural

[2] U. S. Dept. Agr. Yearbook 1898, page 692.

exports were large. Nor is it any wonder that young men went to cities by the thousands, because farming did not pay.

Present farm prices not high for farm conditions.— The city dweller who compares prices with 1896, and perhaps remembers his boyhood days on the farm, thinks that the farmer of to-day must be getting rich. He supposes that every farmer rides in an automobile. Some persons go so far as to blame the farmer's automobile for the high cost of living. As a matter of fact, the percentage of farmers who own automobiles is very small. There are only a few sections where such ownership is common, and even in those sections the landlords are often the ones with the automobiles. Taking the United States as a whole, for every farmer who owns an automobile there are many whose only vehicle of luxury is a spring seat on a lumber wagon.

The census report gives some indication of the wealth of farmers. Thirty-seven per cent of the farmers in the United States are renters. The average value of implements, machinery, and live-stock on the rented farms in 1910 was $699. Part of this is owned by the landlord. Sixty-two per cent of the farmers own part of the land that they operate. The average value of land, buildings, implements and machinery, and live-stock on these farms was $6754. One third of these farms were mortgaged and one sixth of them included some rented land.

The average farmer is making interest on his capital and farm wages for his labor.[3] The interest is not high enough to attract any large amount of money out of the cities. The wages are not high enough to cause any large number of men to move from city to country, but they are high enough to keep most of the boys on the farm. Probably enough of them are now staying, but the effect of this will not be felt for a few years. Just now, we are feeling the effect of the great exodus of boys during the nineties. Now boys are studying agriculture and are staying on the farms. They are responding to the increased prices by becoming farmers, as their fathers are responding with increased crops.

Probable future prices.— We must not expect that the value of farm products on the farm will drop much unless farming is again over-done. The present conditions may result in too many boys' staying on the farm and in temporary overproduction. There will also be overproduction of some products every year, as there has always been. For example, thousands of tons of cabbages were never harvested in 1912 because the crop was so overproduced that the price did not pay for hauling. Thousands of bushels of onions were stored in the fall of 1912 and thrown away the following spring because there was no market. The writer saw 2500 bushels rotting in one storage house in Ohio for want of a market. But such conditions soon correct themselves.

[3] U. S. Dept. Agr., Bureau of Plant Industry. Circular 132.

The prices in 1913 were generally abnormally high because of the excessive drought in the preceding summer. But any permanent lowering of the prices of products on the farm must not be expected, at least not unless everything else becomes cheaper. Land now has a value, plant-food has a value. Every farmer knows how to greatly increase his crops, but each added bushel costs more per bushel. The crop yields will continue to be increased if prices rise. They will be decreased if prices fall. There is much land to be reclaimed, but always at much cost. Land that must be drained or irrigated or fertilized or green-manured is expensive. The bushels grown on it are costly bushels. By heavy fertilization or other intensive methods, we can easily increase crops; but after a fair crop is secured every bushel that we get costs more than the preceding bushel. The limit of yield per acre is far from reached, but the period of low cost of production per bushel is passed.

Europe secures larger yields per acre, but even with the low wages the cost per bushel is more. Europe has to pay the farmer much higher prices for nearly all products in order to secure her large yields.

WAYS OF REDUCING THE COST OF FOOD

Reducing the cost of distribution.— We cannot look to the farms for any great reduction in the cost of food. But there appears to be one way in which prices may be lowered to the consumer. From a half to two thirds of the money paid by the consumer never reaches the farmer. Most of this amount is consumed by the exceedingly cumbersome machinery of distribution in cities. Probably half of this excessive increase in price after the cities are reached can be eliminated. But if this is to be done, some persons who are a part of the present system will have to change their occupations. These persons naturally object to any change. The city dweller will also have to learn that when he telephones for a quart of potatoes to be delivered, what he pays the farmer for the potatoes is practically nothing. What he calls the high cost of potatoes is the high cost of delivery and bookkeeping. The first step in reducing the cost of living is to buy more than a quart of potatoes at one time.

Use of cheaper food.— As our population is becoming larger we are being forced to use cheaper kinds of food. Beef is one of the most expensive foods, because so much feed is required in order to produce a pound of it. It has been estimated that a given amount of grain will support five times as many persons as will the meat grown from it. As population increases, the price of grain rises faster than does the price of meat. During the last ten years, corn has risen in price much faster than have steers. This is the reason why farmers are not raising more beef. The childish suggestion that each farmer should raise two steers a year would

result in a very much higher cost of living, if farmers were foolish enough to follow the advice. This advice ignores the fact that we cannot eat the grain and also produce beef from it. Laws are often introduced in Congress and in State legislatures to prohibit the killing of heifer calves, in the apparent assumption that calves live on air. The food in the milk that it takes to produce a given amount of veal will support more persons than will the veal. The longer the calf is fed on milk, the less is the supply of human food. The comparative prices offered for the milk and for the veal produced from it are measures of the comparative need of the city for these products. Hence, calves are not kept long except where milk is cheap. Few cattle are raised except where feed is cheap.

A given amount of feed will produce much more human food in milk than it will in beef. Dairy cows are therefore increasing about as rapidly as population. We keep a little more than one cow for five persons. In addition to milk, this number of cows provides about one veal or one old cow or bull for beef for each family each year.

Hogs are much more efficient users of food than are steers. A given amount of grain will produce many more pounds of pork than it will of beef. For this reason, hogs are increasing in number while beef cattle are decreasing.

Poultry are very efficient users of food. As meat rises in price, more eggs are used. The egg receipts in the seven leading egg markets, New York, Chicago, Boston, St. Louis, Cincinnati, San Francisco, and Milwaukee, were as follows:[4]

1891	5,040,888 cases
1901	8,655,001 cases
1911	14,275,271 cases

From 1890 to 1910 the population of these seven cities, including all the territory now in New York City, increased 78 per cent. The receipts of eggs increased 183 per cent. We are substituting eggs for beef.

When population becomes very dense, roughage and waste products will be used for producing milk. After we have kept all the dairy cows that are needed, we will raise as many beef cattle as can be kept on the remaining supply of roughage and pasture. We are feeding animals less and less on grain that is good for human food. The decreasing number of beef cattle and the tendency to market steers at a younger age are an expression of this condition.

All these changes mean that some persons who once ate meat must now eat less of it. Unfortunately the manual laborers, who are the very ones most in need of meat, are the first to have to go without. We are

[4] U. S. Dept. Agr. Yearbook 1912, page 688.

getting the first intimation of the conditions that have long existed in all densely populated countries. Probably we can support the vast hordes of people that are estimated as our possible future population, but they will not live so well as we live.

Location of factories in villages and small cities.— Comparatively few persons go from city to country. Such a movement is neither necessary nor desirable. It is very difficult for grown persons who have never lived on a farm to become farmers. The best time to learn to farm is in one's youth. But large numbers of persons who are employed in towns and cities now live where they can have land enough to raise part of their food. By locating industries in smaller places and by the increase of trolley lines it is made possible for many workers to live on small plots of ground that will provide for a garden and hens, and sometimes for a cow. This enables the family to greatly reduce the cost of living. At the same time it provides the best kind of work for the children. The number of farms of less than 20 acres increased 25 per cent in the last ten years. A very large proportion of these places are occupied by persons who are employed at some industry other than farming. In a single county without any large cities — Tompkins county, New York — there are about 500 such places.[5]

Small or large farms.— One of the popular suggestions for reducing the cost of food is to reduce the size of farms. But, for general farming, our farms are now too small. Machinery makes it possible for a family to work more land than formerly. The farm that uses two or three workers is a family farm. It will employ a farmer and his sons. Four horses are required for farming with modern machinery, but four horses can raise 80 to 100 acres of general farm crops. Pasture land, woodland, roads, and farmstead make up half the farm in most sections, hence 160 to 200 acres is usually required for efficiency in general farming. In the general farming sections from New York to Nebraska, farms are rapidly changing to the four- to six-horse size. The city, as well as the country, is best off when farms are of an efficient size. With small general farms it is necessary to keep four horses in order to use labor-saving machinery, even if the area is too small to keep the horses busy. There is no benefit to the city dweller in having small farms if the farm horses eat the product. The moderate-sized general farms contribute more per acre to the city food supply than do the small general farms.[6]

Truck and fruit farms may be somewhat smaller, but only a few such farms are required in order to supply our needs. The vast majority of farms must raise hay, grain, potatoes, live-stock, and milk.

Those who would keep the boys on the farm defeat their purpose when

[5] Cornell University Agr. Exp. Sta. Bulletin 295, page 562.
[6] Cornell University Agr. Exp. Sta. Bulletin 295, page 527.

they would reduce the size of farms. The four-horse size mentioned above is a two-man farm. If farms are too small to provide profitable work for the sons, they very wisely leave.

In Jefferson county, New York, it was found that 79 per cent of the boys had left the small farms and only 16 per cent had left the good-sized farms (Table 11).

TABLE 11. RELATION OF SIZE OF FARM TO BOYS LEAVING THE FARM, 674 FARMS, JEFFERSON COUNTY, NEW YORK

Acres farmed	Number of families	Percentage of sons		
		At home	On other farms	Not farmers
30 or less	25	21	33	46
31 to 50	29	52	22	26
51 to 100	171	75	8	17
101 to 150	187	78	10	12
151 to 200	136	72	10	18
Over 200	126	84	8	8

China furnishes an example of a country with small farms. It is estimated that about 75 per cent of the population are farmers. With the little patches, and the hand labor of men, women, and children, each family can produce only a trifle more than it eats. Since there is so little surplus, only a small city population can be supported.

If our population ever becomes as congested as is that in parts of Europe or Asia, we may want smaller farms and may do away with machinery and horses and use men and women to till the land. The reason why we use machinery and horses is because labor is high. Some of the old countries have tried machinery and discarded it, not because of ignorance of the workers but because human labor is cheaper. In most parts of India it is cheaper to cut grain with a sickle than with a binder. How cheaply these people work is a measure of their poverty.

None of these discussions should be construed to favor large "bonanza farms," or large holdings by landlords. Near large cities in the East, many large tracts of land have been purchased in recent years for country homes and as places where wealthy men play at farming. The influence on the agriculture of such regions has been demoralizing. In some parts of the country, particularly in the Middle West, there is a tendency for some persons to buy farms to be run by tenants. The tendency for one individual to acquire a large number of farms for such a purpose is a serious menace. In the opinion of the writer it would be well to have laws that would place some limitation on the size of such holdings.

Restriction of immigration.— Another popular suggestion for decreasing the cost of food is to increase the number of farmers by persuading persons to go from the city to the farms or by the importation of cheap labor for the farms. These suggestions would bring about exactly the opposite condition from the one that is desired. If we continue indefinitely to allow practically unrestricted immigration, we shall in time reach the cheap labor conditions of the Old World. Their yields per acre are attractive, but are secured at what cost! Women and children must work in the fields in order to live. The returns per acre are high, but per worker they are low. It is estimated that the American farmer produces twice as much per worker as does the Belgian peasant and five times as much as does the Chinese peasant. The city dweller must not deceive himself by thinking that he can keep up wages in the city and pay poor wages to the farmer. The European system secures larger yields, but the farmers receive more for nearly all farm products. Their cost of production per bushel is higher in spite of the cheap labor and the high yields.

Perhaps the worst suggestion made for increasing farm production is that we bring in cheap labor of other races to help the farmer. The worst calamity that can ever come to a rural region is to have it settled by two races that will not intermarry after a generation or two.

One of the most serious problems in the country is to maintain schools, churches, and other social institutions. The chief school problem is distance. There are not enough children within convenient distance of a schoolhouse, nor is there usually enough wealth to maintain a good school. If two school systems are to be maintained, they will be poor indeed. The money that is inadequate to maintain one good school system must be divided between two schools, one for each race.

Persons who have never lived in such a community may question the need for two schools. The rural school is the chief social meeting-place of boys and girls of the farm. To a large extent the noon hour and the recess take the place of the evening parties in town. In the United States, whenever any large number of each of two non-intermarrying races have settled in a community, two school systems have resulted. In parts of South America, less racial distinctions have been made and the different races have intermarried.

The physical fact of the scattered population is the chief reason for the poor rural schools of the South and for the high percentage of illiteracy among southern whites. If the Negroes in any prosperous county were replaced by white families, the schools would doubtless be as good as in the North, because there would be enough persons within reach of the school to maintain a good school. Transportation of pupils may be suggested, but the problem remains the same. If every other house is occupied

by a Negro, whatever the school system, there will be only half as many white families in a given area.

The same point applies to churches, granges, social gatherings, cooperative effort, and all things that have to do with the progress of civilization. The greatest obstacle to all such progress in rural regions is distance. Dividing the population into two non-intermarrying classes doubles the problem by doubling the distance.

It is well known in the South that whenever a rural community becomes all white, the land values double and treble. This is primarily because there are then enough persons in a rural community to maintain good schools, churches, and other institutions of civilization. The twofold and threefold increase in land values is a measure of the increased desirability as a home. California furnishes a similar example. When a few Japanese buy land in a community, the land values drop. There are then not enough Americans to maintain the American social institutions that must be kept up if life in the country is to be worth living. Probably a settlement of Americans in a farming community in Japan would have an equally bad effect. The Japanese laws indicate that this is the opinion of the Japanese government.

A high development of the rural community requires a homogeneous population. In the city there may be enough people of each race so that each may maintain its own institutions and its own social relations; but in the country there are too few, even when all are one. The farm community must be enough of a unit so that all will work together socially if the highest development is to be secured.

The primary reasons that lead families to leave the farms and go to town usually are, to get the benefit of better schools, churches, and other social institutions, and to have better medical attention. Whenever a large part of the population is made up of an alien race, the reasons for such a movement are many times increased. The menace to health of a less educated race is also a powerful factor in preventing progress in a mixed community.[7]

The price of products in the United States is based on American wages and the American standard of living. If one farmer can get cheap labor so that he can sell on the American wage market but produce on a low wage cost, he may do well for a time; but when others also get the cheap labor, he is worse off than before.

The men who do the manual labor inherit the land. This has been true even of the Negro. Much of the richest land of the South is in the hands of the Negroes. They do not yet own much of the land; but what difference does it make, whether they own or rent, if they are the persons

[7] Nesbitt, Dr. Charles T. The health menace of alien races. World's work, November, 1913, page 74.

who make up the rural community? Omitting Oklahoma, there are 222 counties in the South where the number of black farmers exceeds the number of white farmers. In 15 of these counties less than one in ten of the farmers are white. In 53 of the counties there are more Negroes than whites who own their farms. In all these 222 counties the hired labor is nearly all black. As a result of these conditions the white population is very scattered. The better the land, the more likely are the white persons to move to town. If the land is good enough it can be farmed by Negro tenants and the owner thus allowed to live in a town or a village. It takes good land to stand this treatment. The poorest land has required the intelligence of a white operator in order to make it yield a living. The black prairie soils of Alabama and Mississippi are striking examples. These are very fertile limestone soils. They readily grow alfalfa, corn, oats, wheat, cotton, and many other crops. In all this region there is a tendency for the white population to move to the towns and villages, where schools are available. The white and the black population of Montgomery, Alabama, are almost equal, but in Montgomery county outside the city there are nearly six blacks to one white. A large proportion of these few white persons live in small villages, so that the proportion on farms is still less. In Selma there are nearly as many whites as blacks, but in Dallas county outside of this city there are almost nine black persons for one white. A large proportion of these few white families live in small villages, so that the proportion on the farms is still less.

The results on production have been just as bad. These rich soils, which should be producing as Iowa soils do, do not produce their own mules or all the feed for them. Little but cotton is grown, and the yields of this are very poor for the soil. There are few regions where poorer use is being made of the natural advantages.

These facts are given as an illustration of the general economic laws that govern changes in farm population and farm ownership. When persons who can under-live the present farmers settle in a farm community, they tend to displace the present farmers, partly because they live for less and partly because, living for less, they make the community undesirable as a home. At the same time the agriculture is made poorer rather than better. The same principles have frequently been illustrated in the northern States, but the statistics are not so readily available. When we settle any persons in a rural community as workers we should consider, not whether they will pay us a profit as laborers, but whether they will make the kind of persons that we desire for our future farmers.

Some persons are now advising that the lowest class of our immigrants be turned to the farms. These immigrants have an entirely different

experience and a different standard of living from any who have yet settled on northern farms. It is certain that any considerable settlement of such persons in any rural community would drive out the present farmers. It is certain also that a poorer agriculture would be established. Of late years it has been a popular thing for public speakers and writers with very limited knowledge of the facts to berate the American farmer. Unfortunately some persons who have occupied important positions have contributed to the confusion, until many of the thinking persons in cities have been convinced that our farmers are inferior to those in any other country of the world. The misleading and often untrue statements of the wonderful things done in Europe are largely responsible for this unfortunate condition. One of the popular errors is to compare the potato crop of New York with that of Europe in order to show how little our farmers know about farming. It would be just as accurate to compare the apple crop of Europe with that of New York in order to show what superior farmers we have in New York. Or we might compare the corn yields of Champaign county, Illinois, with those of Europe, in order to show our superiority. Our wheat yields are compared with those of England as a means of showing how poorly we farm, but most of our wheat is grown with much less rain and with a less favorable climate. Our farmers also pay better wages and get less for their wheat. Such unscientific and misleading comparisons have done much harm.

As our farms are the foundation of our wealth, so the farmers are the foundation of our civilization. No high civilization can long endure that is not based on a high type of citizenship on the farms. No temporary inflation of production can compensate for bringing in a lower class of farmers.

A large proportion of our farm boys are now staying on the farms. The great movement to cities has been checked. We do not need to look to any other country for more farmers or farm laborers. Throughout the North our farms have always been "family farms." The farmer and his family do nearly all the work. Less than half of the farmers (46 per cent) hire any labor. Most of the hired men are the sons of neighboring farmers. Some individuals always clamor for cheap labor, but such labor is not needed. If it were supplied in large amount the family-farm system would be destroyed. This system results in the best citizenship and in the best agriculture. How much more efficient it is than hired labor can be testified to by business men who have tried to run large farms. Such farms often get large yields and are often referred to as examples of what can be done, but with very rare exceptions they furnish examples of how to lose money.

If any considerable amount of low-class labor settles on our farms it

will result, as it always has resulted, in driving out the better farmers, and will at the same time result in a poorer agriculture. The aim of public-spirited persons and of government endeavor should be to make the farm a more attractive place, so that it will hold intelligent and forceful men, not as landlords, but as workers. We should raise the rural community to the standard of the American boy and girl, rather than look around the world for some one who is willing to accept life on a farm regardless of its standards.

Restriction of exportation of phosphorus.— The four important plant foods that are needed in increasing quantities are nitrogen, phosphorus, potassium, and calcium. We have an inexhaustible supply of calcium in our limestone and of nitrogen in the air. Both of these can be supplied to our soils to the extent that prices of crops warrant. Fortunately most of the American soils in the northern States seem to have a fair amount of potassium. There is enough of this in the mines of Germany to last for an indefinite time. But the supply of phosphorus in American soils is often deficient. This is the chief constituent in most of the chemical fertilizers. The chief source of phosphorus is from the phosphate rock of the Carolinas, Tennessee, and some other southern States. The amount of this rock seems to be limited.

According to Dr. C. G. Hopkins, of the University of Illinois, we are now exporting each year as much phosphorus in this rock as would be contained in twice the entire wheat crop of the United States. Germany controls the exports from her potash mines, which appear to be inexhaustible. We give no attention to the exportation of the phosphorus that we are likely to need on our own farms. An investigation of the phosphorus supply and our probable future needs should be made, and the question of limitation of export should be given careful attention, before it is too late.

SUMMARY

The wholesale prices of farm products are not very high when compared with the average for the past 73 years. The prices that farmers receive for animal products are higher than the average, but the prices received for crops are generally as low as, or lower than, the 73-years average. For a generation after the opening of the western prairies, prices were extremely low. In comparison with this period prices are high, but, when comparing with a long period of time, the prices that farmers receive are not very high.

Crop yields east of the Mississippi River have been rapidly increasing in the last ten to fifteen years. Before that time there was a period of low yields, because of low prices.

Farmers know how to raise much larger crops, and do raise larger

crops whenever they are convinced that prices will be high enough to make it pay to do so.

In nearly every county in the United States there is considerable land that can be brought into use by clearing, drainage, irrigation, or other means. This land will allow for a considerable increase in production.

But there is very little that can be done to increase production without increased cost. Land that must be cleared, drained, irrigated, green-manured, or heavily fertilized is expensive land. The bushels grown on it are expensive bushels. After a fair yield has been secured, every bushel that we get usually costs more than the preceding bushel. Farmers quickly adjust their yields to prices. If present prices continue, production will be increased. If prices rise, production will be considerably increased.

There does not seem to be any likelihood that prices paid to farmers can be permanently lowered, but there are ways of decreasing the cost of food to the consumer.

The machinery of distribution after products leave the farm is unnecessarily expensive. Much of this cost can be eliminated.

Of necessity we are using more foods that come from plants and less animal foods.

By locating factories in villages where the workers can have gardens, the cost of living may be reduced.

The popular suggestions to reduce the size of farms and to import cheap labor to help farm are more likely to result in expensive, rather than cheap, food. Small farms that follow the same type of farming usually have less left to sell than do moderate-sized farms, because so much is consumed by the horses and the men who work the land.

A restriction of immigration by raising the standard for admission is strongly advised as one of the best means of preventing the cost of living from rising very much higher, and as a means of checking the present tendency to lower the standard of living.

In consideration of the striking need for phosphorus over large areas of the United States, an investigation of the phosphorus supply with a view to restriction of export is recommended.

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SWEET-PEA STUDIES—IV

CLASSIFICATION OF GARDEN VARIETIES OF THE SWEET PEA

By ALVIN C. BEAL

ITHACA, NEW YORK
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The sweet-pea trials, 1913

CONTENTS

SWEET-PEA STUDIES—IV

CLASSIFICATION OF GARDEN VARIETIES OF THE SWEET PEA

Alvin C. Beal

(*Received for publication January* 3, 1914)

SWEET-PEA TESTS AT ITHACA

The great epoch in the growing of sweet peas in America began with the introduction of the Eckford varieties in 1886, and received impetus from the introduction of the American variety Blanche Ferry in 1889. About this time it was discovered that, owing to climatic conditions, California was adapted to the production of large quantities of sweet-pea seed. This made it possible to meet the heavy demand that arose during the last decade of the nineteenth century, when sweet peas were unprecedentedly popular. At that period sweet-pea exhibitions were held, and flowers were grown in almost every garden. No other annual flower, to the writer's knowledge, has ever approached the sweet pea in the magnitude of its growth in popular interest.

Then came a wane for a few years, apparently due to the cultural methods employed and to the appearance of diseases. But the flower is again coming into its own. In the meantime the waved type has been developed. In the closing days of Mr. Eckford's busy life he saw the awakening interest in sweet peas on the part of the English people. The introduction of the variety Countess Spencer in 1904 raised this interest to fever heat, and a national sweet-pea society — which is now one of the largest horticultural associations in the world, numbering over one thousand subscribers — was organized in England.

Many growers have undertaken the work of further improving this flower, and, due to this and to the sportive tendencies of the waved type of sweet peas, the number of varieties has increased at a rate hitherto undreamed of. In the contest for novelties many growers have found the same sports, have named them, and have sent them out, so that we have more than one name for the same variety. It appears also that some growers have been in too great a hurry to send out novelties before assuring themselves that their varieties were fixed. Sometimes a seedsman thought he had a fixed stock, only to find, after having introduced it, that it varied wherever grown. The novelties for 1911 include not less than eighty-five varieties. For several years past the offerings have exceeded fifty varieties a year, so that now there are almost a thousand variety names of sweet peas.

With the view of furthering interest in the sweet pea as a flower for the masses, the American Sweet Pea Society, at its inception in July, 1909, decided to establish trial grounds for the elimination of synonyms and the testing of new varieties. The trial grounds were established at Cornell University, through a cooperative arrangement between the Department of Horticulture of the New York State College of Agriculture and the society. The latter was to supply the seed, and the former was to conduct the tests in conjunction with a committee on nomenclature appointed by the society. In order to enlist the largest number of growers in the work of the trial grounds each year, a circular letter was sent to every firm offering new varieties of sweet peas. The growers named below have sent varieties for trial:

Great Britain: Aldersey & Marsden Jones, Tilston, Malpas, Cheshire; W. E. Alsen, Denmead, Waterlooville, Hants; R. H. Bath, Wisbech; S. Bide & Son, Farnham, Surrey; James Box, Haywards Heath, Sussex; William Deal and E. J. Deal, Kelvedon; Silas Cole, Northampton; T. H. Dipnall, Hadleigh, Suffolk; Dobbie & Co., Edinburgh, Scotland; Miss Hilda Hemus, Upton-on-Severn; Kelway & Son, Langport, Somersetshire; E. W. King & Co., Coggeshall, Essex; Alexander Malcolm, Duns, Scotland; S. Miller, Newport, Isle of Wight; G. Stark & Son, Great Ryburgh, Norfolk; Sutton & Sons, Reading; Robert Sydenham, Birmingham; W. J. Unwin, Histon, Cambridgeshire; Watkins & Simpson, London.

United States: A. T. Boddington, 342 West Fourteenth Street, New York; W. Atlee Burpee & Co., North Fifth Street, Philadelphia; Peter Henderson & Co., 35 Cortlandt Street, New York; C. C. Morse & Co., 48–56 Jackson Street, San Francisco; W. W. Rawson & Co. (now Fottler, Fiske, Rawson Company), Boston; Waldo Rohnert, Gilroy, California; Vaughan's Seed Store, 31–33 West Randolph Street, Chicago; James Vick's Sons, Rochester, New York; Ant. C. Zvolanek, Bound Brook, New Jersey.

From this list it will be seen that most of the really progressive growers who are intensely interested in the permanent development of sweet-pea culture have assisted in the work. To these and to all who have assisted in the work the American Sweet Pea Society and the New York State College of Agriculture are indebted. It is hoped that the cordial support hitherto given to the work may be continued for the further advancement of the sweet pea in popular favor.

On receipt of the seeds a list of all the varieties, with the date of their receipt, was made. A card index was also prepared, so that any arrangement of the varieties could be made. On these cards the trial number was entered so that the variety could be quickly found in the field.

OUTDOOR TESTS

In addition to the purposes of the trials before mentioned, it was thought desirable to make some cultural tests as to the effect of the time, depth, and thickness of planting on the resultant crop. With this in view, plantings were made in the fall and in the spring.

Successive fall plantings

Many of the dealers sent in seeds promptly, and in order to test the feasibility of growing sweet peas successfully from fall planting the trials were begun very soon after the writer entered upon the work. Plantings made at this station at intervals of ten days, from October 20 to November 30, 1909, gave the following results:

TABLE 1. RESULTS FROM FALL PLANTINGS

Variety	Date of planting (1909)	Condition of soil	Number of seeds sown	Number of seeds that germinated	First bloom (1910)
Mont Blanc....	October 20	Excellent.......	120	22	June 6
	October 30	Slightly frozen...	120	14	June 6
	November 10	Excellent	120	58	June 6
	November 20	Excellent..	120	20	June 15
	November 30	Very wet and cold.	120	5	June 20
King Edward VII.......	October 20	Excellent	120	69	June 19
	October 30	Slightly frozen.... .	120	83	June 19
	November 10	Excellent	120	99	June 19
	November 20	Excellent	120	45	June 19
	November 30	Very wet and cold .	120	6	June 19
Countess Spencer....	October 20	Excellent	120	97	June 20
	October 30	Slightly frozen......	120	92	June 20
	November 10	Excellent	120	87	June 20
	November 20	Excellent	120	77	June 20
	November 30	Very wet and cold .	120	24	June 20

In all these trials there was no top growth, but some plants of the first two plantings were just piercing the surface, when winter set in. The third planting germinated, but the last two did not appear above the surface of the ground until the following April (1910), when they appeared on the 4th and the 15th, respectively.

The results indicate that the planting should be delayed as late as is practicable, but not so late that the seed must be sown in a cold, wet, heavy soil.

Successive spring plantings

The spring plantings were not made at uniformly regular intervals, as were the fall plantings, because of the cold, wet weather of April, 1910, and the heavy rains of May. However, the results are comparable, for the same varieties, from the same consignment of seed, used in the fall plantings were used in these tests.

TABLE 2. RESULTS FROM SPRING PLANTINGS

Variety	Date of planting	Number of seeds sown	Number of seeds that germinated	Date of germination	First bloom
Mont Blanc.....	March 12	120	18	April 15	June 18
	March 22	120	49	April 18	June 20
	April 4	120	92	April 20	June 21
	April 16	120	90	April 30	June 27
	April 27	120	101	May 10	June 30
	May 7	150	141	May 16	July 5
	May 18	125	118	May 30	July 12
	June 1	175	146	June 16	August 18
King Edward VII..	March 12	120	81	April 15	June 25
	March 22	120	103	April 20	June 27
	April 4	120	104	April 27	July 2
	April 16	120	102	April 30	July 5
	April 27	120	110	May 10	July 6
	May 7	120	108	May 18	July 15
	May 18	125	114	May 30	June 30
	June 1	150	133	June 16	August 26
Countess Spencer...	March 12	120	111	April 15	June 30
	March 22	120	117	April 20	July 1
	April 4	120	110	April 27	July 2
	April 16	120	111	May 3	July 4
	April 27	120	110	May 10	July 7
	May 7	120	118	May 16	July 15
	May 18	120	115	May 30	July 20
	June 1	150	131	June 16	August 26

It is very apparent, in view of the results from the germination of the variety Mont Blanc, that white-seeded sweet peas should not be sown until the ground has thoroughly thawed.

The most significant fact in connection with these trials was the manner in which the dry, hot weather hurried forward the April plantings so that they came into bloom together.

The height of the plants varied directly with the time of planting, the first being the tallest. The amount of bloom on all spring plantings

after the first three was much reduced and the length of the stems was considerably less. However, the late April and early May plantings produced a number of blooms, and with more rain and with fertilizers the results would doubtless have been fairly satisfactory.

Due to the dry, hot weather, the June planting did not flower until August, after a very feeble existence. When the mildew appeared in the latter part of August these plants were quickly destroyed, as the disease caught them at the time when they were beginning more rapid growth.

The results of 1910 indicate that plantings of garden varieties made after May 10 are really not worth while.

VARIETY TESTS

Each year a different area has been selected for growing the plants. Soil as nearly uniform as possible has been chosen. The land is plowed in the autumn, and furrows are opened with the plow so that barnyard manure can be placed under the rows preparatory to spring planting. When the furrows are closed, if a slight ridge is left over the row it can be raked down as soon as the surface dries in the spring, thus facilitating early planting. The varieties under test in 1910, 1911, and 1912 were sown in the open ground as early as possible. In 1913 all the varieties were sown in pots in March and were planted later in the field. The results from the latter method were so much better that that method will be continued.

In the first year the rows were 20 feet long and 4 feet apart. Four hundred and five of these rows were planted, giving a total length of row of 8100 feet, or a little over one and one half mile. The total length of row grown in 1911 was 4500 feet, in 1912 it was 3000 feet, and in 1913 it was about 2000 feet. In the first two years a large number of the older varieties were grown, but in the last two years only the leading varieties of the older types were grown. The work has now reached the stage when only one variety of the older type in each color section will be grown for comparison.

A record was made of the number of seeds planted of each variety, and later the number that germinated was recorded. Of the standard varieties 120 seeds were usually planted in each row; with samples that appeared to be of poor quality, however, a good stand was assured by sowing more seeds. The question is sometimes asked whether old sweet-pea seed will grow. An opportunity to test this was afforded by seeds sent in by Mr. Morse for study of the obsolete types. This seed was saved some years before, when variety tests were being made, and the following results shed some light on the question:

TABLE 3. GERMINATION OF OLD SWEET-PEA SEED IN 1910

(The asterisk denotes white-seeded varieties)

Variety	Crop of	Number planted on April 15	Number germinated	Date of germination
Black Brown Stripe	1904	125	19	May 9
Purple Brown Stripe	1902	125	40	May 8
Striped Celestial	1902	125	92	May 7
Columbia	1902	125	51	May 7
Juanita	1903	150	42	May 7
Daybreak	1904	150	75	May 7
Gaiety	1901	125	40	May 7
Wawona	1903	125	77	May 7
Duchess of York	1904	125	103	May 6
Splendour	1903	125	82	May 10
Large Yellow Red	1902	125	75	May 10
Large Yellow Open Form* (Many seeds of this variety are split)	1901	175	3	May 10
Fairy Queen	1901	125	61	May 10
Alice Eckford	1904	175	104	May 6
Lady Beaconsfield	1903	125	78	May 8
Countess of Shrewsbury	1902	125	47	May 12
Delight	1903	125	98	May 8
Lemon Queen	1903	133	53	May 10
Peach Blossom	1904	125	105	May 4
Crown Princess of Prussia	1903	175	31	May 10
Ignea	1903	125	85	May 4
Carmine Invincible	1904	150	127	May 4
Brilliant	1904	125	112	May 4
Cardinal	1904	125	107	May 4
Bronze King	1901	125	14	May 6
Empress of India	1904	152	90	May 6
Emily Lynch	1904	125	115	May 4
Coronet	1902	125	15	May 4
Orange Prince	1903	125	46	May 12
Meteor	1902	150	52	May 10
Alba Magnifica*	1903	175	50	May 4
Queen of England*	1903	150	62	May 4
Dorothy Vick	1903	125	99	May 10
Princess Victoria	1903	125	87	May 6
Rising Sun	1902	125	46	May 14
Duchess of Edinburgh	1903	125	57	May 10
Queen of the Isles	1904	125	99	May 4
Adonis	1904	150	126	May 4
Miss Hunt	1904	125	102	May 4
Novelty	1903	125	62	May 8
Fluted Primrose*	1901	150	1	May 14
Ovid	1904	125	114	May 4
King Edward VII	1909	90	85	May 4
Countess Spencer	1909	90	83	May 5
Oddity	1904	125	115	May 4
Inconstancy*	1902	175	6	May 12
Golden Gleam*	1904	150	101	May 4
Mont Blanc*	1909	175	146	May 4

It is apparent that the white-seeded varieties lose their vitality in greater degree than do the black-seeded varieties of the same year's crop Nearly all varieties from the 1904 crop gave as good results as were obtained, in general, from the 1909 crop.

Only a small number of seeds were received of the new varieties and of the novelties. The smallest number of seeds of any variety was five, but in several cases only eight or ten were received. When a few seeds of a variety were to be sown it was arranged to sow one or two other varieties in the same row, leaving a space of eighteen inches between two separate varieties. In the past season, 1913, the length of row was reduced to ten feet because of the greater ease of supporting the plants and because in many cases only five to ten seeds were received. If an equal number of plants were obtained, one half or all of a ten-foot row could be planted to a variety. A crosswalk six feet wide separated each section. This allowed for spraying the plants when necessary.

The varieties were arranged according to color, for the purpose of easy comparison in the determination of synonyms and in the estimation of the value of varieties, relative productiveness, and other points. The arrangement insured the varieties' being sown or planted at the same time, on as nearly as possible the same soil, and with the same exposure.

The question of a suitable support was given considerable thought. After an investigation of the various forms of wire netting suitable for the purpose, it was found that its expense was too great to allow of its use with this area of sweet peas. The method adopted was to place a seven-foot stake at the end of each row and use heavy twine for supporting the plants. The twine was stretched along one side of the row and back on the other, enclosing the plants. While this method was reasonably economical it was not very satisfactory, for the reason that the expansion and contraction of the twine prevented it from supporting the plants properly. The slackened strings allowed the wind to topple the plants alternately back and forth It was found that this could be overcome by placing the supports closer together. In 1913 the use of the string support alone was abandoned, and a strip of wire netting twenty-four inches wide was used near the ground. It was found that this provided a better support for the young plants, for if they were torn loose by the wind they could be tied up with raffia. As soon as the plants were well started, little difficulty was experienced in keeping them straight. The use of strings for supporting the tops of the plants has been found satisfactory, provided the plants do not reach a total height of more than four feet. If under garden conditions the plants grow taller than four feet, the width of the strip of netting should be correspondingly increased.

The rapidly increasing number of varieties of sweet peas offered since Mr. Eckford began the improvement of the flower has made it imperative that some method of classifying varieties should be adopted. In the autumn of 1896 the Sunset Seed and Plant Company issued a small work entitled "Sweet Pea Review," in which was proposed a classification of sweet peas based on form. Average specimens of the largest and most perfect standards of Eckford's introductions of 1896 and 1897 were selected, and, each being laid down naturally, with the front side uppermost, a circle was drawn around it just touching the extreme edges. Within each circle an outline drawing representing a certain type was made.

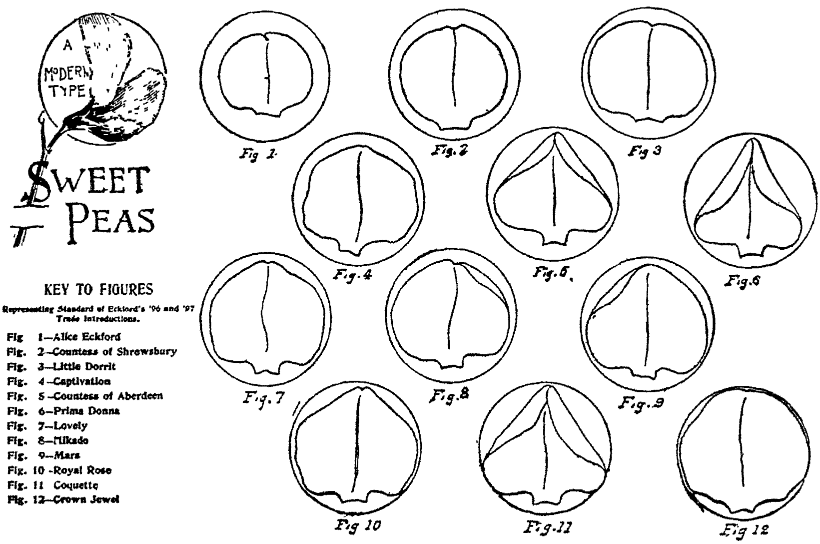


FIG. 24.—*Classification of sweet peas, suggested by the Sunset Seed and Plant Company, San Francisco, California*

The diameter of the circles was thirty-eight millimeters, or a trifle over one and one half inch, and represented the *grandiflora* size as this company understood it. A perfect type of flower is illustrated as one in which the farthest projections of the standard, wings, keel, and calyx exactly touch the thirty-eight-millimeter circle. The ninety varieties of sweet peas grown by the company were classified into twelve types.

This classification based on form has not been adopted by growers of sweet peas. The method was copyrighted, which possibly had something to do with the fact that it never became popular. A more important reason, no doubt, is the fact that the size, and also to some extent the form,

of sweet-pea flowers are dependent on the culture that they receive. Under a hot sun the various flowers on a plant assume different forms according to the length of time that the blossoms have been open. At the present time the system would not be very serviceable in describing varieties of the waved form, since the amount of the waving or the folding of the standard varies with the variety, the strain, or the stock, as well as with the cultural conditions.

Although varieties were rapidly multiplying, seedsmen continued to list the names alphabetically. Mr. Burpee, who catalogued one hundred and fifty varieties in 1899 — the most extensive collection offered up to that time by any seedsman, so far as the writer can learn — classified them in this manner.

METHODS OF DESCRIPTION

The Classification Committee appointed at the Bicentenary Celebration at London in 1900 adopted the following scheme of classification, based on color instead of on form:

Selfs: Flowers with one color only; to be classified as:

White Selfs	Blush Selfs	Yellow or Buff Selfs
Pink Selfs	Rose Selfs	Carmine Selfs
Purple and Maroon Selfs	Crimson Selfs	Lavender Selfs
Mauve Selfs	Blue Selfs	Salmon and Orange Selfs

Flakes: Flowers with a decided ground color, on which are flakes and stripes of another color; the color of the flakes to determine the class:

Red and Rose Flakes	Mauve Flakes
Maroon and Purple Flakes	Blue Flakes

Bicolors: Flowers with two colors, one found in the standard and the other in the wings; the color of the standard to determine the class:

Red and Rose Bicolors	Salmon and Orange Bicolors

Fancies: Flowers of several colors, and such as are not provided for in other divisions. The ground color to determine the class:

White Ground Fancies	Yellow or Buff Ground Fancies

Picotee Edge: Flowers of one or more colors, but having an edging of a distinct color or shade around the standard and the wings. No subdivision is as yet considered necessary.

The seedsmen soon began to list their varieties under the principal colors, but as a rule no classification was made as to form.

The Sweet Pea Annual for 1906 gives the following color classes: White, Crimson and Scarlet, Cerise, Rose and Carmine, Pink, Blush, Blue, Yellow

Shades, Orange, Lavender, Mauve, Violet and Purple, Magenta, Picotee Edged, Red Stripes, Blue Stripes, Bicolors, Fancies. This is substantially the classification that was used until 1911, except that the Cream Pink and the Marbled class were added.

The color classes for 1911 show that Crimson and Scarlet were separated, while the Orange class has been divided into Orange Pink, Orange Scarlet, and Salmon Shades. The Picotee Edged class is subdivided into Cream Grounds and White Grounds. A Lilac class has been added. There is a total of twenty-five classes.

During this period the National Sweet Pea Society of England listed the best varieties under each color class, including the best variety of the old type, which was indicated by an asterisk.

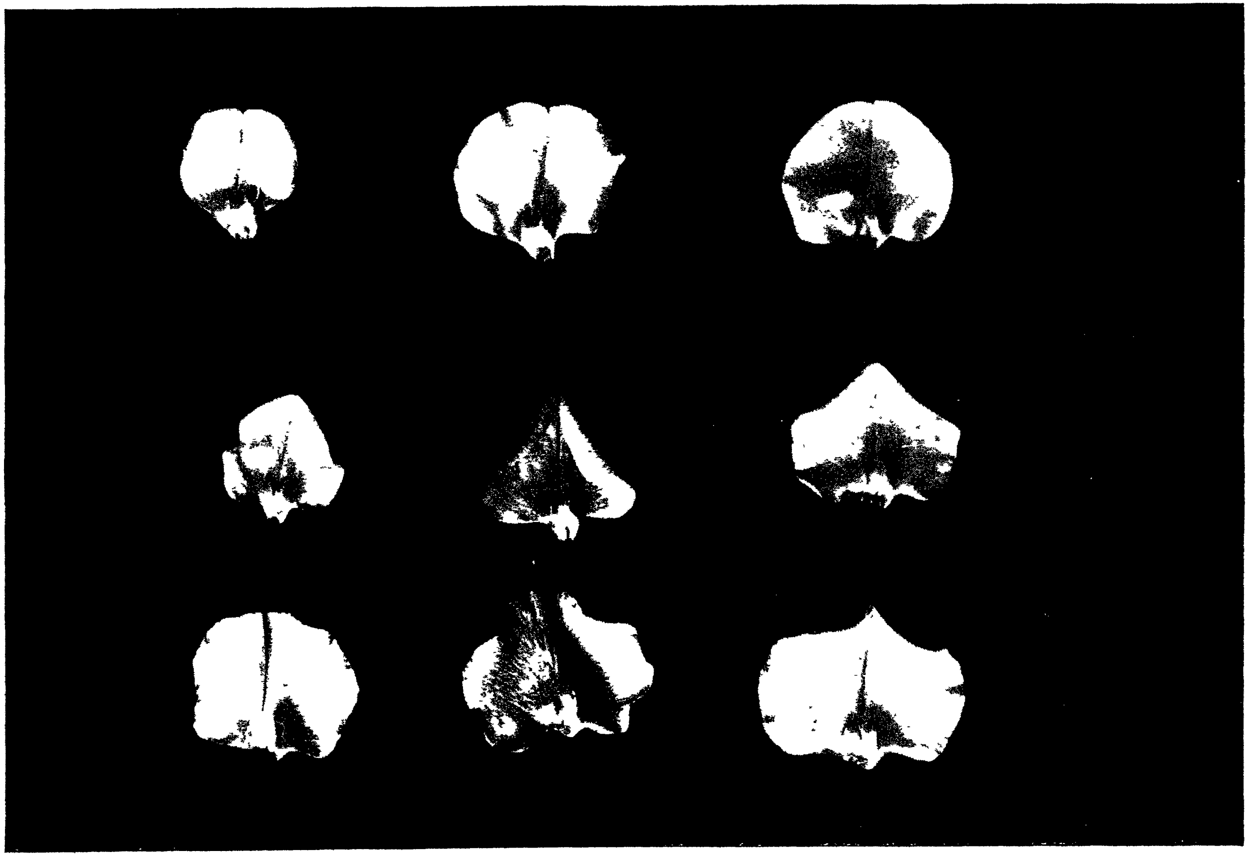
The Sweet Pea Annual for 1913 gives the following color classes: Bicolor; Blue; Blush; Carmine; Cerise; Cream, Buff, and Ivory; Cream-pink (Pale); Cream-pink (Deep); Crimson; Fancy; Lavender; Lilac; Magenta; Marbled and Watered; Maroon; Maroon Purple; Maroon Red; Mauve (Dark); Mauve (Pale); Orange-pink; Orange-scarlet; Picotee Edged (Cream Ground); Picotee Edged (White Ground); Pink (Deep); Pink (Pale); Rose; Salmon Shades; Scarlet; Striped and Flaked (Purple and Blue); Striped and Flaked (Chocolate on Gray Ground); Striped and Flaked (Red and Rose); White. A total of thirty-two classes.

When one considers the advance from a classification that comprised only White, Cream or Light Yellow, Light Blush, Light Pink, Deep Pink, Rose, Red and Scarlet, Shades of Orange and Salmon, Pink and White, Blue and White, Claret and Maroon, Striped and Variegated, Lavender and Light Blue, and Blue and Purple, one can appreciate the fact that the classification of sweet peas has undergone evolution. Moreover, this indicates more clearly than does anything else the marvelous development of the flower.

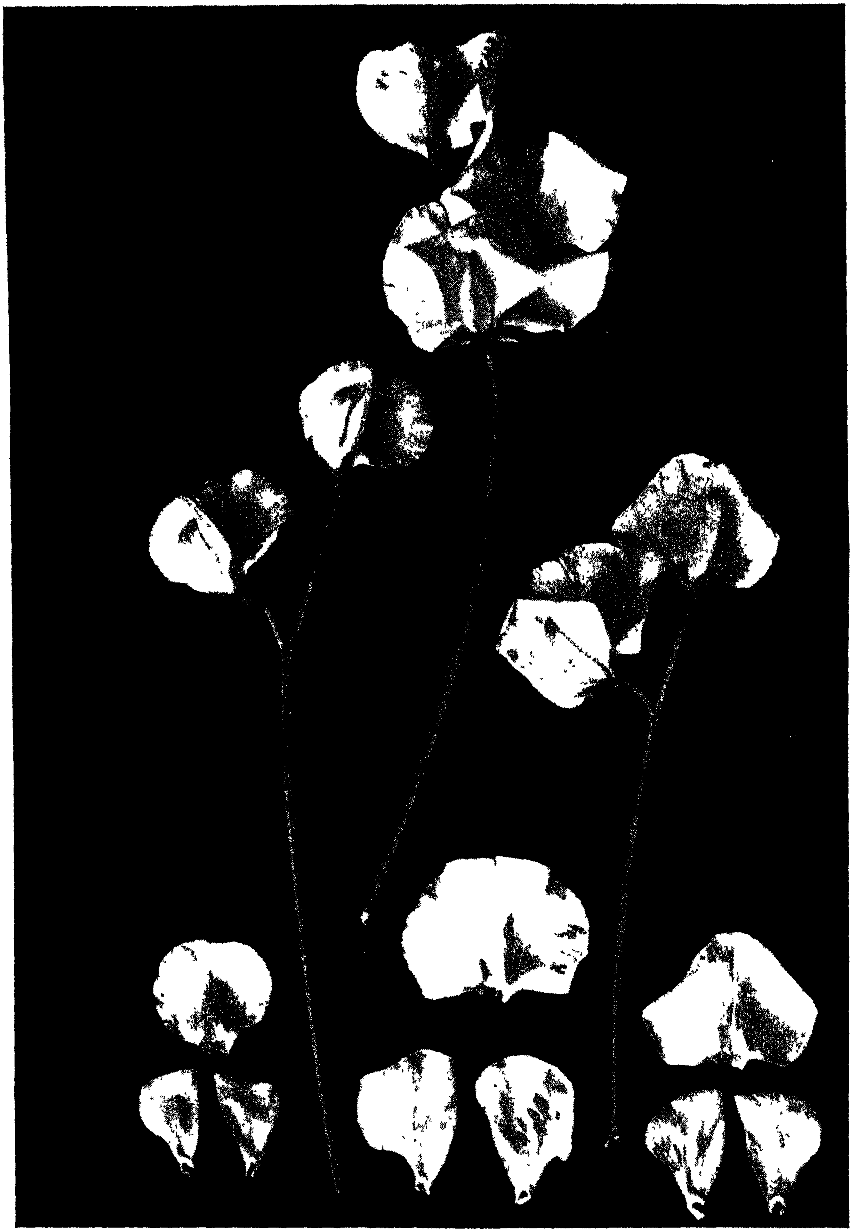
In the Field Notes on Sweet Peas, 1907, edited by L. L. Morse, it is stated that the most natural classification is according to color, and that most seedsmen recognize such an arrangement. Mr. Morse then calls attention to the fact that another classification, almost as important as that of color, is that of form, referring to the size and the shape of the standard. He classes the varieties as follows:

Hooded form		*Open form*	
Large......	Aurora	Large.......	Triumph
Medium...	Countess of Radnor	Medium.....	Blanche Ferry
Small......	Blushing Beauty	Small.......	Crown Princess of Prussia

The Countess Spencer group, which was just coming in, was classified as "very large." This group has since been recognized universally as



Open Form — Alba Magnifica, Shasta, Golden Rose
Hooded Form — Butterfly, Admiration, Dorothy Eckford
Waved Form — Elsie Herbert, Apple Blossom Spencer, White Spencer



Mrs. Sankey Spencer
Queen of England *Dorothy Eckford*

distinct in form. The size of the varieties is of less importance at the present time, for the waved, or Spencer, sweet peas are usually of very large size, and if any of the older varieties are to persist in the trade they must be of the largest size. The varieties with medium-sized blooms are now obsolete, as were the small-flowered varieties of Morse's list.

The principal characters on which a classification of sweet peas may be based are habit of the plant, form of the flower, and color of the flower. In habit of plant, the dwarf, bush, winter-flowering, and garden types are recognized. In general there are two main groups, the dwarf forms and the tall forms, the latter including the winter-flowering and garden types. The form of the flower has been evolved from the reflexed form, through the open and the hooded, to the waved form. The open form with the flat standard may be classified into the notched and rounded types. There are various degrees of hooding, of which the extreme form is the snapdragon, now grown only as a curiosity. In like manner we find various degrees of waviness in the waved, or Spencer, form; these can be placed in groups according to the amount of waviness, being equal to, less than, or greater than, Countess Spencer under the same conditions. The writer proposes the following classification of sweet peas:

Garden type	*Winter-flowering type*	*Dwarf type (Cupid)*
Open form	Open form	
Hooded form	Hooded form	
Waved form	Waved form	

The dwarf type is not of sufficient importance to be subdivided, but it embraces varieties with flowers of both open and hooded form.

Under each form the varieties are classified by color, using the color classification of the English National Sweet Pea Society. So far as possible, the Répertoire de Couleurs was used in determining the color of all the varieties of sweet peas grown. In the description of each variety the relative size of the flower is recorded.

The descriptive blank shown on page 228 was prepared for recording the data on varieties. The plantings in the field were labeled by number only, and the corresponding number was placed under its heading on the card; so that in making the records it was not known who sent the variety under examination. The data on the upper part of the card were not entered until after the season was over. This practice was followed in order to keep the records free from the possibility of bias as to the estimate placed by others on a variety. The information given is therefore our own, except when it is specifically stated to be the opinion of another.

CORNELL VARIETY TEST OF SWEET PEAS

NAME .... Trial No. ....

SYNONYMS .... **TYPE OF BLOOM** Open Hooded Waved

COLOR Class Bicolor, Blue, Blush, Carmine, Cerise, Cream, Buff, and Ivory, Cream Pink, Deep Cream Pink, Crimson, Fancy, Lavender Lilac, Magenta, Marbled Maroon, Maroon Purple, Maroon Red, Dark Mauve, Pale Mauve, Orange-Pink, Orange-Scarlet, Picotee Edge on white, Picotee Edge on cream, Deep Pink, Pale Pink, Rose, Salmon Shades, Scarlet, Striped Blue, Striped Chocolate, Striped Red, White.

COLOR Standard Uniform Color No.
Color shades No. to
Stripes Ground
Flakes Ground
Picotee Edge
Veins Back
Fades from to

Wings Uniform Color No.
Shades No. to
Stripes Ground
Flakes Ground
Picotee Edge
Veins Back
Fade from to

SIZE flower small medium large very large **standard** small medium large very large
wings small medium large very large

FORM standard flat reflexed hooded hooded slightly hooded much waved (Spencer) waved slightly waved much
wings conceal keel partly open spreading drooping hooded waved upright and pointed

SHAPE standard notched sides notched top round pointed shell narrow base broad base auriculate
wings long short broad narrow

SUBSTANCE sunproof burns wet weather injures

FRAGRANCE none moderate much **BLOOMER** shy medium profuse

SEASON first bloom **USE** home market exhibition

STEM No. fls. varies to **Length** short medium long **Strength** weak medium strong
Position of flowers face variously face one way equidistant irregular close wide apart

PLANT dwarf bush medium tall very tall **Growth** weak slender stout **Vigor** healthy diseased mildew yellowing marbled
Stock pure mixed true to type not true true to name not true **Leaflet** narrow broad pointed round
light green dark green **Tendril** green colored clinging non-clinging

DESCRIPTIONS OF VARIETIES

OPEN-FORM VARIETIES

Bicolor (Blanche Ferry group)

BLANCHE FERRY

Originated by ————. *Introduced by* D. M. Ferry & Co., 1889.

Donated by A. T. Boddington, and W. Atlee Burpee & Co.

Description in brief — Medium size, red and white, extra early, open form, notched standard.

Description in detail — Color of standard scarlet 156 (3–4); wings lilacy white 7 (4). Flower of medium size, open form; standard of medium size, open form, with notched top; wings long and narrow, concealing the keel. Flowers two to three, on short to medium stems. Very fragrant. Bloom profuse, lasting well on the plant. Sunproof. A garden or market variety. Plant of short, slender growth. Leaflets narrow, pointed, dark green. Seed black, large.

Comparison — Extra Early Blanche Ferry, Earliest of All, Reselected Extreme Early Earliest of All, are similar, but earlier. A difference of sixteen days has been noted in the earliness of the varieties of this group.

Remarks — The first and epoch-making variety. The introducer illustrated it with a color plate, the first sweet-pea novelty of American origin thus figured in an American catalogue For history see Bulletin 320 of this experiment station, page 691, and Bulletin 319, page 625.

BLUSHING BRIDE

Originated by ————. *Introduced by* Joseph Breck & Co., 1891.

Description in brief — A rose-and-white variety.

Comparison — " Resembles Blanche Ferry in color, but is larger."— Breck's catalogue, 1891.

Remarks — Said to be a sport of Painted Lady. Was grown for a time by Boston florists.

BRIDE OF NIAGARA

Originated by Mrs. O. H. Day. *Introduced by* James Vick's Sons, 1896.

Description in-brief — A double-flowered strain of Blanche Ferry.

Remarks — Interesting historically as the first double sweet pea. This variety was originated by Mrs. O. H. Day, Niagara Falls, New York, and was announced by Vick in 1896. The name was selected by ballot. The variety was introduced in 1896, when it was described as having a clear pink banner, and white wings and keel. The flowers often had two or three banners.

EARLIEST OF ALL

Originated by Thomas Gould. *Introduced by* Burpee, 1898.

Donated by Boddington, Burpee.

Description in brief — Flower of medium size, red and white, open form, notched standard; an extra early variety.

Comparison — Color same as Blanche Ferry. Not so vigorous as Blanche Ferry in the field.

EXTRA EARLY BLANCHE FERRY

Originated by ———————. *Introduced by* Ferry, 1895.

Description in brief — Flower of medium size, red and white, open form, notched standard; an extra early variety.

Comparison — Similar to Blanche Ferry, but earlier. Blanche Ferry and Extra Early Blanche Ferry are more vigorous than Earliest of All.

FLORENCE FRASER

Originated by ———————. *Introduced by* J. C. Vaughan, 1904.

Description in brief — Flower of medium size, red and white, open form.

Comparison — Differs from Blanche Ferry in greater vigor of plant and longer-stemmed flowers.

LADY DALKEITH

Originated by ———————. *Introduced by* L. L. May & Co., 1894.

Description in brief — "Red and white, very free flowering." — May's catalogue for 1894. Not listed in later catalogues.

LITTLE DORRIT

Originated by Henry Eckford. *Introduced by* Eckford, 1895.

Description in brief — Red and white, open form.

Comparison — Resembles Blanche Ferry, with possible exception of shape of the standard.

NELLIE JANES

Originated by ———————. *Introduced by* R. & J. Farquhar, 1892.

Description in brief — A pink-and-white variety.

Synonyms — Painted Lady under another name.

Remarks — Grown by Boston florists.

PAINTED LADY

Description in brief — Standard rose, wings white tinged with pink.

Comparison — Blanche Ferry was introduced as "Improved Painted Lady."

Synonyms — Nellie Janes is the same as Painted Lady.

Remarks — Catalogued in all old trade lists. Earliest mention by Philip Miller in Gardeners' Dictionary, 1731. Probably the same form as that described by Burmann as *Lathyrus Zeylanicus*, he supposing that it came from Ceylon. Appears to have been omitted in American catalogues since 1899, but in some English lists later than this.

RESELECTED EXTREME EARLY EARLIEST OF ALL

Originated by Gould. *Introduced by* Burpee, 1902.

Donated by Burpee, Boddington.

Description in brief — Flower of medium size, red and white, open form, notched standard, extra early.

Comparison — Blanche Ferry, Extra Early Blanche Ferry, and Earliest of All are similar in color of flower and in habit of plant.

Bicolor (Miscellaneous group)

BEACON

Originated by ——————. *Introduced by* Robert Bolton, 1906.

Description in brief — A medium to large, open-form variety, with cerise standard and creamy wings.

Comparison — An improved Duke of York.

BLUE BELL

Originated by ——————. *Introduced by* May, 1894.

Description in brief — Described in Bulletin 111 of this experiment station as follows: "Flowers small. Standard convex, wedge-shaped. Color, standard pink, wings purple-rose. Bloom sparse."

Remarks — Catalogued for next five years after introduction.

BRONZE KING

Originated by ——————. *Introduced by* Haage & Schmidt.

Donated by C. C. Morse & Co., for evolution studies.

Description in brief — A small, open-form variety, with coppery pink standard and white wings.

Description in detail — Color of standard violet-old rose 145 (1); wings creamy white 10 (1). Flowers small, open form; standard small, flat, stiff, with notched top; wings long and narrow. Burns badly. Plant of tall, strong growth.

Remarks — Offered by Henderson in 1894.

BRONZE PRINCE

Originated by Eckford. *Introduced by* Eckford (?), Bull, 1885.

Description in brief — "Flowers large. Standard flat. Color, purple-red, the wings the more purple."— Bulletin 111 of this station.

Synonyms — Light Blue and Purple is the same variety. Joanna Theresa is the same.

Remarks — One of the first of the Eckford varieties, and one that remained in the trade for at least fifteen years. Mentioned in Gardeners' Chronicle [n. s., vol. 20 (1883), p. 264].

COUNTESS OF SHREWSBURY

Originated by Eckford. *Introduced by* Eckford, 1896.

Donated by Morse, for evolution studies.

Description in brief — A small variety, with rosy standard and white wings.

Description in detail — Color of standard violet-rose 154 (1), fading to lilacy white 7 (4) at the edge; wings lilacy white 7 (1). Flower small, open form; standard small, flat, sometimes reflexed, with apical notch; wings of medium size, upright, and pointed, concealing the keel. Flowers two to three, on medium stems. Fragrance questionable. Bloom moderately profuse, continuous. Standard fades and burns at the top.

Comparison — Lady Beaconsfield is similar, but is on a primrose ground.

DUKE OF YORK

Originated by Eckford. *Introduced by* Eckford, 1894.

Description in brief — Smaller than medium size. Open-form variety, with rose-pink standard, and wings light primrose shaded with pink.

Comparison — Has been described as Blanche Ferry on a primrose ground. Emily Lynch was the improved form of this variety.

EMPRESS OF INDIA

Originated by Eckford. *Introduced by* Eckford, 1891.

Donated by Morse, for evolution studies.

Description in brief — A medium-sized, open-form variety, with rosy standard and wings.

Description in detail — Color of standard violet-rose 154 (4), purple-rose 150 (1) on the back; wings mauve-rose 153 (1), veined with solferino-red 157 (3–4). Flower of medium size, open form; standard of medium size, flat, with round top; wings long and narrow, concealing the keel. Flowers two, on medium stems. No fragrance. Bloom moderately profuse, continuous Plant of medium height and slender growth. Leaflets narrow, pointed; tendrils green.

Comparison — Blanche Ferry has wings of a purer white.

GEM

Originated by ————. *Introduced by* May, 1894.

Description in brief — Red and white.

Remarks — Does not appear in later catalogues.

LADY BEACONSFIELD

Originated by Eckford. *Introduced by* Eckford, 1893.

Donated by Morse, for evolution studies.

Description in brief — A medium-sized, open-form flower; standard light pink on primrose, wings light primrose.

Description in detail — Color of standard lilacy white 7 (4) on a yellowish white ground; wings yellowish white 13 (3). Flower of medium size, open form; standard of medium size, flat, with notched top; wings medium to large, long, of medium width, partly open. Flowers two to three, on long, strong stems. Very sweet-scented. Bloom profuse, continuous. Plant of medium to tall, strong growth. Tendrils colored.

Comparison — Countess of Shrewsbury is similar in color but is on a white ground. Coquette is said to be the large, hooded form of Lady Beaconsfield.

Remarks — One of the best of the old varieties.

TRIUMPH

Originated by Eckford. *Introduced by* Eckford, 1897.

Description in brief — A large, open-form variety, with rose-colored standards and crimson-pink wings.

Comparison — Said to be similar to Empress of India, but is much larger. Royal Rose is the hooded form of this color.

Blue and Purple Shades (Bright blue)

BLUE BELLE

Originated by S. Bide & Sons. *Introduced by* ————.

Donated by Bide, 1912.

Description in brief — A grandiflora variety, with violet-blue standards and violet-purple wings.

Description in detail — Color of standard bishop's violet 189 (1), sometimes marked at base with violet-purple; wings violet-purple 192 (1). Flower of medium size, open form; standard of medium size, flat; wings long, narrow, drooping. Flowers

two, on slender stems of medium length. Moderately fragrant. Moderately productive. Flower fades, and lasting quality is poor. Plant of tall, slender growth. Leaflets broad.

FLORA NORTON

Originated by Morse. *Introduced by* Vaughan, 1904.

Donated by Boddington, 1910.

Description in brief — A medium-sized flower of a lavender-blue shade.

Description in detail — Color of standard and wings lavender-blue 204 (1); the clearest of the blues. Flower of medium size, open form; standard of medium size, flat, with round top; wings long and broad, partly open. Flowers two, on medium stems. Moderately fragrant. Bloom profuse. Sunproof. A garden variety. Plant of tall, strong growth. Leaves and stems light green; tendrils green.

Remarks — A beautiful blue. Unfortunately the flower is too small for exhibition, but the variety is worthy of retention because of the color. Flora Norton Spencer is not the same color.

MID BLUE

Originated by Dobbie & Co. *Introduced by* Dobbie, 1909.

Donated by Dobbie, 1910; Burpee, 1911.

Description in brief — A medium-sized, " deep sky blue " flower.

Description in detail — Color of standard bluish violet 203 (2–3); wings lavender-blue 204 (2–3), the lower edges fading to almost white. Flower medium large, open form; standard medium large, flat, occasionally reflexed in very hot sunshine, with round top; wings long and broad, spreading. Flowers two to three, equidistant on long, strong stems. Very fragrant. Bloom medium. Sunproof. Plant of tall, strong growth. Leaflets narrow, pointed.

Comparison — Practically identical with Zoe (Biffen, Miss Hemus, Unwin, 1906). Standard lighter than that of Lord Nelson and darker than that of Flora Norton.

ZOE

Originated by R. H. Biffen. *Introduced by* Biffen, Miss H. Hemus, W. J. Unwin, 1906.

Comparison — Practically identical with Mid Blue (Dobbie), and has prior introduction.

Blush

ALICE ECKFORD

Originated by Eckford. *Introduced by* Eckford, 1895.

Donated by Morse.

Description in brief — Pink and buff, shaded on white.

Description in detail — Color of standard pale rosy pink 129 (1); wings lilacy white 7 (1). Flower small, open form; standard small, flat or with reflexed edges, with notched top; wings very long, longer than standard, narrow, concealing the keel. Flowers two to three, usually three, on medium stems. Bloom profuse, continuous. Flowers burn badly, and last poorly while on the plants. Plant of medium height and slender growth. Leaflets narrow, pointed.

Comparison — Sensation is the large, hooded form of this variety.

Remarks — Too small for the present day.

Comparison — Color is similar to that of Dorothy Vick, but the flowers are larger and have longer stems.

Carmine and Rose (Rose group)

ADONIS

Originated by ———. *Introduced by* James Carter & Co., 1882.

Description in brief — A medium-sized flower, with rosy pink standard, and wings of lighter shade.

Description in detail — Color of standard purple-rose 150 (2); wings mauve-rose 153 (1). Flower of medium size, open form; standard of medium size, flat or reflexed, with notched top and apical fold; wings long and broad, concealing the keel. Flowers two, irregularly placed on long, medium stems. Moderately fragrant. Bloom profuse, continuous. Burns badly. Plant of tall, slender growth. Tendrils green.

Comparison — Novelty and Miss Hunt are similar in color. but are larger.

Remarks — Burpee offered this variety in 1884, Breck in 1885.

AMERICAN QUEEN

Originated by Morse. *Introduced by* Burpee, 1902.

Description in brief — Large, open form, magenta-rose self.

Comparison — Lord Kenyon and Lord Roseberry are similar in color, but are of hooded form.

MIMA JOHNSTON

Originated by Eckford. *Introduced by* Eckford, 1908.

Description in brief — "Bright rose carmine, shaded salmon, wings soft rose."— Eckford's catalogue.

Comparison — Morse considers this variety an open form of Bolton's Pink, of medium size.

MISS HUNT

Originated by Eckford. *Introduced by* Eckford, 1887.

Donated by Morse, for evolution studies.

Description in brief — A medium-sized. open flower, rosy pink.

Description in detail — Color of standard lilac-rose 152 (2–3); wings violet-rose 154 (2–3); back a trifle deeper-colored. Flower of medium size or larger, open form; standard medium to large, flat, with notched top; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Bloom profuse, continuous. Burns slightly. Plant slender. Leaflets narrow, pointed; tendrils green.

Comparison — Larger, brighter, better-shaped flowers than Adonis. A little lighter than Novelty. Ovid, Lord Kenyon, and Lord Roseberry are the hooded forms of this variety.

Remarks — Offered by Henderson in 1889.

NOVELTY

Originated by Eckford. *Introduced by* Eckford, 1895.

Donated by Morse, for evolution studies.

Description in brief — A medium-sized, rosy scarlet flower.

Description in detail — Color of standard lilac-rose 152 (4); wings violet-rose 154 (4). Flower of medium size, open form; standard of medium size, flat; wings long and

broad, concealing the keel. Flowers two to three, on very long stems of medium strength. Bloom moderately profuse. Burns slightly. Plant of medium height and slender growth. Leaflets narrow, pointed, dark green; pedicels red.

Comparison — A little deeper-colored flower than Miss Hunt; a distinct plant, with darker green leaves, less vine, and less profuse bloom than that variety.

Cream-Pink

AGNES JOHNSON

Originated by Eckford. *Introduced by* Eckford, 1903.

Donated by Morse, 1910.

Description in brief —A medium-sized flower; standard cream shaded with rose-pink, wings cream flushed with pink.

Description in detail — Color of standard pale blush 137 (4); wings mauve-rose 153 (1–2). Flower of medium size, open form; standard of medium size, flat, with round top; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Moderate fragrance. Bloom moderate. Plant of tall, strong growth. Leaves pointed; tendrils green.

Comparison — Very similar to Sunrise and Evening Star, but larger.

CORONATION

Description in brief — Blush, with pink at the back of the standard.

Comparison — Similar to Duchess of Westminster.

DUCHESS OF WESTMINSTER

Originated by Eckford. *Introduced by* Eckford, 1900.

Description in brief — Apricot tinged with pink, which is deepest at the base of the standard; wings delicate rose-pink.

EVENING STAR

Originated by Morse. *Introduced by* Vaughan, 1904.

Donated by Vaughan, 1910.

Description in brief —" A pale buff flushed salmon pink."— Vaughan's catalogue.

Description in detail — Color of standard maize yellow 36 (1) on a violet-rose 154 (3) ground; wings mauve-rose 153 (1). Flower of medium size; standard of medium size, flat, with round top; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Bloom moderate. Plant of tall, strong, healthy growth. Tendrils green.

Remarks — Morse states that before its introduction this variety was called Open-form Venus.

MAY PERRETT

Originated by Eckford. *Introduced by* Eckford, 1908.

Description in brief — Ivory, flushed with buff or creamy pink.

Remarks — See May Perrett Spencer.

SUNRISE

Originated by Morse. *Introduced by* Vaughan, 1904.

Donated by Vaughan.

Description in brief — Bright pink suffused with primrose.

Description in detail — Color of standard and wings mauve-rose 153 (1–2); standard flushed with violet-rose 154 (4). Flower of medium size; standard of medium size, flat, with notched top; wings long and broad, partly open. Flowers two, sometimes three, on good stems. Moderate fragrance. Bloom profuse. Burns slightly in hot sun. Plant of tall, stout growth. Leaflets narrow, pointed.

Remarks — Morse states that before its introduction this variety was called Katherine Tracy on cream.

ZARINA

Originated by Biffen. *Introduced by* Miss Hemus, 1909.

Donated by Miss Hemus, 1910.

Description in brief — A beautiful, large, decorative flower, of open form and soft salmon-pink color.

Description in detail — Color of standard pale rosy pink 129 (1–2); wings pale lilac-rose 130 (1–2) on a buff ground. Standard open, sometimes slightly waved; wings short and narrow. Flowers two to three, on fairly strong stems. Moderately fragrant. Bloom very profuse, continuous. Many double and triple standards. Plant of short, slender growth. Leaflets narrow, pointed; tendrils numerous and very much colored; color in axils of leaves and leaflets; calyx dark reddish brown.

Comparison — Queen of Spain in open form.

Remarks — A true stock.

Crimson and Scarlet (Crimson group)

CARDINAL

Originated by Eckford. *Introduced by* Eckford, 1886.

Donated by Morse, for evolution studies.

Description in brief — A medium-sized, open-form, scarlet-crimson variety.

Synonyms — Same as Carmine Invincible at this station. Captain Sharkey (Breck, 1889) is the same variety. (See Bulletin 127 of this station.)

Remarks — Although J. S. Eckford states that this was introduced in 1887, the writer finds Cardinal (Eckford) catalogued by Breck in 1886. In Breck's catalogue for 1887 is found Cardinal (Eckford, 1886).

CARMINE INVINCIBLE

Originated by Thomas Laxton. *Introduced by* Laxton, 1886.

Donated by Morse, for evolution studies.

Description in brief — A medium-sized, open-form, scarlet-crimson variety.

Description in detail — Color of standard claret 167 (2–3); wings dull dark crimson 168 (1). Flower smaller than medium size, open form; standard of medium size, with edges reflexed, sometimes twisted or curled; wings long and broad, usually concealing the keel. Substance poor. Flowers two to three, on short, weak stems. Fragrant. Bloom profuse and continuous. Burns badly. Plant of medium height and slender growth. Produces many side branches from the base, giving a heavy row of plants.

Remarks — This variety marked a distinct advance in the improvement of sweet peas. Reputed to be a cross between Invincible Scarlet and Invincible Black. Received an award of the Floral Committee of the Royal Horticultural Society in 1883.

FIREFLY

Originated by Eckford. *Introduced by* Eckford, 1893.

Description in brief — A medium-sized, open-form, bright red variety.

Comparison — Slightly different form from Cardinal. Ignea, Brilliant, Mars, Salopian, and King Edward VII were the hooded forms of this color. King Edward Spencer is the waved form.

INVINCIBLE SCARLET

Originated by Stephen Brown. *Introduced by* Carter, 1866.

Description in brief — A crimson-scarlet variety.

Synonyms — Morse states that this is the same as Carmine Invincible.

Remarks — On July 11, 1865, Mr. Brown gained the first First Class Certificate ever awarded by the Royal Horticultural Society for a sweet pea. This variety was catalogued in the American trade from 1870 until 1900.

KING EDWARD IMPROVED

Originated by ————. *Introduced by* Watkins & Simpson, 1910.

Donated by Watkins & Simpson.

Description in brief — A large, carmine-scarlet variety.

Comparison — An improved strain of King Edward VII.

Remarks — A fixed stock.

KING EDWARD VII

Originated by Eckford. *Introduced by* Eckford, 1903.

Donated by Boddington, 1910; Burpee, 1911, 1912.

Description in brief — A large, carmine-scarlet variety.

Description in detail — Color of standard carmine-purple 156 (4); wings carmine-purple 156 (1–2). Flower large, open form; standard large, flat or occasionally slightly hooded; wings large, long and broad, concealing the keel. Substance good. Flowers three to four, on long, strong stems. Fragrance very slight or none. Bloom profuse, continuous. No burning. A garden or market variety. Growth tall, strong, and healthy.

Remarks — This variety represents the acme of the crimson-scarlet varieties of the open or the hooded form. King Edward Spencer is the waved form.

Crimson and Scarlet (Scarlet group)

BAKER'S SCARLET

Originated by ————. *Introduced by* Bakers, 1909.

Description in brief — " Almost pure scarlet. Same shade as Queen Alexandra but not so well formed as standard turns backward."— Morse's Field Notes on Sweet Peas.

Comparison — Introduced as an Improved Queen Alexandra.

FADELESS SCARLET GEM

Originated by Morse. *Introduced by* Morse, 1907.

Donated by Morse, 1910.

Description in brief — A bright scarlet variety.

Description in detail — Color of standard and wings French purple 161 (1–2). This strain of Scarlet Gem does not turn purple. Flower of medium size, open form;

standard of medium size, flat, with round top; wings long and broad, concealing the keel. Flowers two to three, usually two, on long, strong stems. Bloom profuse, continuous. A garden variety. Plant of medium height and slender growth. Foliage of a bluish green color.

Remarks — Is not fadeless; it soon loses its bright appearance, but is free from the objectionable purple tinge in the original variety.

SCARLET GEM

Originated by Eckford. *Introduced by* Eckford, 1904.

Donated by Burpee, 1911.

Description in brief — A bright scarlet variety.

Description in detail — (See the description preceding, of Fadeless Scarlet Gem.)

Comparison — Fadeless Scarlet Gem is supposed to be a better selection. No difference was seen in the trials at this station in 1911.

Remarks — Unfortunately the flower turns dark soon after it opens, becoming almost black.

W. E. GLADSTONE

Originated by ————. *Introduced by* May, 1894.

Description in brief — " Brightest shade of scarlet."— May's catalogue, 1894.

Fancy

SYBIL ECKFORD

Originated by Eckford. *Introduced by* Eckford, 1906.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — A large, creamy white variety.

Description in detail — Color of standard and wings creamy white 10 (3). Flower large, open form; standard large, flat, occasionally with notched top; wings large, spreading. Flowers two, irregularly placed on medium stems. Moderate fragrance. Moderately productive. Plant of tall, moderately strong growth.

Comparison — An open-form Marchioness of Cholmondeley.

Lavender

CREOLE

Originated by Morse. *Introduced by* Burpee, 1897.

Donated by Morse, 1910.

Description in brief — A variety with pinkish lavender standard and lavender wings.

Description in detail — Color of standard pale light lilac 187 (4); wings heliotrope 188 (1), with back of ageratum blue 201 (1). Flower large; standard large, flat; wings large, long and broad. Flowers two to three, usually three, on medium stems. Very fragrant. Bloom profuse, continuous. Plant of strong, tall growth.

Remarks — Not more than fifty per cent true. Morse states, however, that the variety was withdrawn because of the impossibility of getting it more than seventy-five per cent true.

PRINCESS MAY

Originated by Laxton. *Introduced by* Laxton, 1893.

Description in brief — A variety with pale mauve standard and lavender wings. Flower of medium size.

Comparison — Superseded by Lady Grizel Hamilton.

Remarks — Offered in the United States by Henderson in 1894.

Magenta-Rose

CALYPSO

Originated by Eckford. *Introduced by* Eckford, 1900.

Description in brief — A magenta-flushed and -veined mauve flower, of medium size and open form.

Marbled

AZURE FAIRY

Originated by ———. *Introduced by* R. H. Bath, 1910.

Description in brief — " French grey ground marbled pale blue."— Bath's catalogue.

Remarks — When grown in 1910 this variety was very unfixed. The majority of our plants were Helen Pierce, with a few David R. Williamson. We believe this variety has been improved.

HELEN PIERCE

Originated by Morse. *Introduced by* Morse, 1905.

Description in brief — White-veined, mottled and marbled with bright blue.

Description in detail — Standard marbled and flaked with bluish violet 203 (3) on a purplish-tinted white ground 6 (3–4); wings lilacy white 7 (3–4); base of petals not colored; back of standard heavily marbled with blue; lower edges of wings and base of standards often fleshy white 9 (1–2). Flower of medium size, hooded form; standard of medium size, hooded slightly, with round top; wings long and broad, partly open. Flowers two to three, on long, strong stems. Moderately fragrant. Bloom profuse, continuous. Sunproof. Plant of medium height and strong growth.

Remarks — Distinct. One of the indispensable varieties for a complete collection.

Maroon Shades (Claret group)

CARMEN SYLVA

Originated by Laxton. *Introduced by* Laxton, 1892.

Donated by Morse, for evolution studies.

Description in brief — Standard claret at base, shading to almost white edges; wings lilac.

Description in detail — Color of standard carmine 116 (1), becoming lighter toward edges, which are rosy white 8 (2–3); wings lilac 176 (4), edges lobelia blue 205 (1). Flower small, open form; standard small, flat, with narrow base and notched top; wings short and narrow. Flowers two to three, generally two, equidistant on medium stems. Very fragrant. Moderately productive. Burns slightly. Plant of tall, fairly strong growth. Leaflets narrow, pointed; tendrils green.

ETNA

Originated by Laxton. *Introduced by* Laxton, 1892.

Donated by Morse, for evolution studies.

Description in brief — Standard amaranth-red, with light edges; wings rosy magenta.

Description in detail — Color of standard amaranth-red 168 (4), back purple-brown 166 (3–4); wings rosy magenta 169 (1). Flower small, open form; standard small, flat, with narrow base; wings long and narrow. Flowers two, sometimes three, on slender stems of medium length. Plant of strong, vigorous growth.

Comparison — Vesuvius is much the same, but is more blue.

Remarks — One of the most famous of Laxton's varieties.

RISING SUN

Originated by Laxton. *Introduced by* Laxton, 1892.

Donated by Morse, for evolution studies.

Description in brief — Standard carmine-purple, with rosy white edges; wings mauve-rose.

Description in detail — Color in center of standard carmine-purple 156 (2), with edges rosy white 8 (4), wings mauve-rose 153 (1) to violet-rose 154 (1). Flower small, open form; standard small, reflexed, with notched top; wings long, very narrow, partly open. Moderately fragrant. Moderately productive. Burns badly. Stems short and weak. Plant of short, weak, slender growth. Leaflets narrow, pointed.

Remarks — One of the worst varieties to burn in hot weather.

VESUVIUS

Originated by J. C. Schmidt. *Introduced by* Schmidt, 1886.

Donated by Morse, for evolution studies.

Description in brief — Color of flower magenta and violet-purple.

Description in detail — Color of standard magenta 182 (3–4), and rosy white 8 (4) at the edges; wings bishop's violet (purple) 189 (4), and bright violet-purple on the back. Flower small, open form; standard small, flat, stiff, notched; wings long and narrow. Bloom profuse. Plant of tall, strong growth.

Comparison — Carmen Sylva is similar, but is more carmine.

Remarks — Offered by Joseph Breck in 1887; by Farquhar in 1886

Maroon Shades (Maroon group)

BLACK KNIGHT

Originated by Eckford. *Introduced by* Eckford, 1898.

Donated by Boddington, 1910; Burpee, 1910.

Description in brief — A very deep maroon.

Description in detail — Color of standard nearest to rich pansy-violet 191 (4), but with more red than 191; wings rich pansy-violet 191 (1–2), veins darker. Back of standard is glossy. Flower large, open form; standard large, flat, with notched top; wings long and broad, concealing the keel. Flowers two to three, usually two, on stems of moderate length. Fragrance slight. Moderately productive. Plant of tall, strong growth. Leaflets narrow, pointed; tendrils green; pods green.

Remarks — One of the darkest varieties, and the best of its color in the old type.

BLACK MICHAEL

Originated by Eckford. *Introduced by* Eckford, 1905.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — A large, pure maroon self.

Description in detail — Color of standard deep carmine-violet 174 (3–4); wings a little lighter. Flower large, open form; standard large, edges reflexed, round top with loop; wings long and broad, concealing the keel. Flowers two, seldom three, on long, strong stems. Plant of medium height and slender growth. Leaflets narrow, pointed, dark green; the entire plant has a blue cast; pods colored on the edge.

Comparison — General effect similar to Black Knight.

Synonyms — Regina, introduced as an Improved Black Michael, appears to be the same.

BOREATTON

Originated by Eckford. *Introduced by* Eckford, 1888.

Description in brief — A deep maroon self, with a medium-sized, open-form flower.

Comparison — This variety is a little lighter than Stanley. Boreatton, Stanley, and Black Knight form a series with gradually deepening color.

CARDINAL WOLSELEY

Originated by ———. *Introduced by* May, 1894.

Description in detail — In Bulletin 111 of this station this variety is described as follows: "Flowers large. Standard flat, slightly wedged. Color, standard crimson, wings maroon, rich. Bloom somewhat profuse."

Remarks — Shown in color illustration on back cover of May's catalogue for 1895. The introducer called the color a deep crimson.

EMPRESS OF INDIA

Originated by ———. *Introduced by* May, 1894.

Description in brief — "Darkest shade of purple."— May's catalogue.

REGINA

Originated by Bolton. *Introduced by* Bolton, 1908.

Donated by W. W. Rawson & Co., 1910.

Description in brief — A dark maroon self.

Synonyms — Seems to be Black Michael. Bolton called this variety an improved Black Michael.

STANLEY

Originated by Eckford. *Introduced by* Eckford, 1893.

Donated by Burpee, 1911.

Description in brief — A large, open-form, deep maroon self.

Comparison — Is deeper-colored than Boreatton, but not so dark as Black Knight.

Remarks — Reputed to be a cross between Captain of the Blues and Splendour.

Maroon Shades (Maroon and Violet group)

BLACK

Donated by Morse, for evolution studies.

Description in brief — A medium-sized, dark violet variety.

Description in detail — Color of standard dark violet 193 (4); wings rich pansy-violet 191 (1), back 191 (4). Flower of medium size, open form; standard of medium size, flat, with narrow base and notched top; wings long and narrow. Bloom profuse. Plant of tall, strong growth.

Synonyms — Invincible Black is the same variety.

Remarks — One of the oldest varieties. Mentioned in sweet-pea literature as early as 1793, and catalogued by Thorburn of New York in 1824.

NEGRO

Originated by ——— *Introduced by* **H. J. Jones, 1908.**

Description in brief — Deep maroon and dark blue flower.

PEACOCK

Originated by ———. *Introduced by* Jones, 1908.

Description in brief — Standard red, wings blue.

SULTAN

Originated by ———. *Introduced by* Laxton.

Description in brief — Standard maroon; wings lilac, bordered with blue.

Comparison — Superseded by Monarch.

Mauve

CAPTIVATION

Originated by Eckford. *Introduced by* Eckford, 1895.

Donated by Burpee, 1910, 1911, 1912.

Description in brief — A medium-sized, purple-magenta variety.

Description in detail — Color of standard and wings bluish lilac 183 (2–3); wings a lighter tint. Flower of medium size, open form; standard of medium size, irregular, sometimes crumpled, with round top; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Very fragrant. Bloom profuse, continuous. Burns slightly. Plant of medium height and strong growth. Leaflets broad, pointed; pedicels red; calyx often colored.

Remarks —A distinct variety.

PRINCESS LOUISE

Description in brief — Standard light magenta-pink, wings lilac.

Synonyms — Hutchins gave this as a synonym of Violet Queen in his catalogues for 1894, 1895, 1896, and 1897.

Remarks — Offered in United States by Burpee in 1887, and listed each year until 1898. Burpee published a color plate of Princess Louise, Invincible Carmine, and Bronze Prince in his catalogue for 1887. This is the first color plate of sweet peas in an American catalogue.

THE QUEEN

Originated by Eckford. *Introduced by* Eckford, 1887.

Donated by Morse, for evolution studies.

Description in brief — A small flower, purplish mauve.

Description in detail — Color of standard and wings purplish mauve 186 (2–3). Flower below medium size, open form; standard below medium size, flat, with slightly notched top; wings long and narrow, partly open. Flowers two to three, equidistant on stems. Fragrance moderate. Bloom profuse. Burns badly. Plant of tall, moderately strong growth. Leaflets narrow, pointed; tendrils green.

Comparison — Violet Queen is deeper and more blue.

Remarks — An unattractive variety.

VIOLET QUEEN

Originated by ———. *Introduced by* Carter, 1878.

Donated by Morse, for evolution studies.

Description in brief — A small, open flower; standard vinous-mauve, wings violet-purple.

Description in detail — Color of standard vinous-mauve 184 (2–3); wings bright violet-purple 190 (1), becoming more blue as flower withers. Flower small, open form;

standard small, flat, wedge-shaped, with notched top and narrow base; wings long and narrow. Flowers two to three. Bloom profuse. Burns badly. Plant of tall, moderately strong growth. Leaflets narrow, pointed.

Comparison — The Queen is similar, but lighter. Emily Eckford is the perfected form.

Remarks — Messrs. Carter advertised this variety by means of a colored plate in their catalogue. This was the first sweet pea so figured. Henderson offered it to the American trade in 1882.

Orange Shades (Orange-pink group)

EVELYN BYATT

Originated by ——————. *Introduced by* Watkins & Simpson, 1906.

Description in brief — A brilliant scarlet-orange variety.

Description in detail — Color of standard reddish old rose 142 (4); wings old rose 144 (1), back purple-rose 150 (1). Flower of medium size, open form; standard of medium size, flat, without apical notch; wings large, long, nearly as long as standard, broad, partly open. Flowers two to three, usually three, on long, strong stems. Bloom profuse. Burns very badly. Plant of tall, strong growth. Leaves narrow, pointed; tendrils green.

Comparison — More attractive than Gorgeous.

HERBERT SMITH

Originated by Holmes. *Introduced by* Robert Sydenham, 1908.

Description in brief — Orange-pink in color.

Comparison — Introduced as an Improved Gorgeous.

Orange Shades (Orange-scarlet group)

COUNTESS OF POWIS

Originated by Eckford. *Introduced by* Eckford, 1897.

Description in brief — "Glowing orange suffused light purple."— Originator's description, catalogue, 1897.

GORGEOUS

Origindted by Morse. *Introduced by* Burpee, 1899.

Donated by Burpee, 1910, 1911.

Description in brief — A medium-sized variety. Standard orange-scarlet; wings rose, tinged with orange.

Description in detail — Color of standard reddish old rose 142 (4); wings bright rose 128 (1), strongly tinged with orange. Flower of medium size, open form; standard of medium size, flat; wings short and broad, partly open. Fragrance slight. Bloom profuse. Burns badly. Stems medium in length and strength. Plant of medium height and strong growth.

Comparison — A deeper and brighter color than Countess of Powis, Meteor, and Orange Prince, which form a series in the order named.

HETTY GREEN

Originated by H. E. Ward. *Introduced by* Bolton, 1907.

Description in brief — "Bright orange scarlet, wings rosy crimson."— Catalogue of National Sweet Pea Society.

METEOR

Originated by Eckford. *Introduced by* Eckford, 1893.

Donated by Morse, for evolution studies.

Description in brief — Orange-pink, wings orange-rose.

Description in detail — Color of standard rosy flesh 134 (2–3); wings violet-rose 154 (1). Flower of medium size, open form; standard of medium size, flat; wings long and broad. Flowers two, on short or medium stems. Fragrant. Bloom profuse, continuous. Burns badly. Plant of medium height.

Comparison — A slightly deeper color than Orange Prince.

MILDRED WARD

Originated by Ward. *Introduced by* Sydenham, 1907.

Description in brief — An orange-scarlet variety.

ORANGE PRINCE

Originated by Eckford. *Introduced by* Eckford, 1886.

Donated by Morse, for evolution studies.

Description in brief — " A bright orange pink."— Hutchins' catalogue.

Description in detail — Color of standard rosy flesh 134 (1); wings violet-rose 154 (1). Flower of medium size, open form; standard of medium size, reflexed, sometimes crumpled, with notched top; wings large, long and broad. Flowers two, on strong stems of medium length. Burns badly. Plant of medium height and slender growth. Leaflets narrow, pointed.

Remarks — Received award by Floral Committee of the Royal Horticultural Society in 1883. Offered in United States by Breck in 1887.

Picotee Edged (Lavender and Mauve group)

BLUE EDGED

Originated by Major Trevor Clarke. *Introduced by* Carter, 1860.

Synonyms — Blue Hybrid was probably identical.

Remarks — This variety is given in the Sweet Pea Annual, and in Sweet Peas Up to Date (edition of 1910), as first introduced in 1883. This is an error of date. The variety was catalogued by Vick as early as 1872, if not earlier. The first of the picotee-edged blues.

CAPTAIN CLARKE

Originated by ————. *Introduced by* C. Sharpe & Co.

Description in brief — White-edged and penciled with carmine; wings edged with blue.

Description in detail — Color of standard shaded violet-rose 154 (2–3) on a lilacy white 7 (4) ground; wings lilacy white, shaded lilac-mauve 196 (1). Flower small, open form; standard small, flat, with notched top; wings short and broad, partly open. Flowers two to three, usually three, equidistant on medium stems. Moderately fragrant. Bloom profuse. Plant of tall, healthy growth. Leaflets broad, pointed; tendrils green.

Remarks — Formerly known also under name " Tricolor." Columbia, another tricolor variety, is striped. Offered by Breck in 1885.

SPLENDID LILAC

Donated by Morse, for evolution studies.

Description in brief — A medium-sized flower, with a lilac-blue standard, and white wings edged with blue.

Description in detail — Color of standard bluish lilac 183 (4). back 183 (1); wings white, edged and shaded with ageratum blue 201 (1–4). Flower of medium size, open form; standard of medium size, flat, wedge-shaped, with narrow base and notched top; wings long and narrow. Flowers one to two, sometimes only one, on short stems. Plant of very tall, strong growth. Leaflets narrow, pointed, dark green.

Remarks — An unattractive variety, due to poor contrasts in color. Offered by Burpee in 1887.

Pink

BRIDESMAID

Originated by Morse. *Introduced by* Vaughan, 1904.

Description in brief — A medium-sized, deep pink variety.

Description in detail — Color of standard mauve-rose 153 (1), center violet-rose 154 (3); wings mauve-rose 153 (1). Flower of medium size, open form; standard of medium size, flat, with notched top; wings short, partly open. Flowers two, on medium stems. Bloom profuse. Plant of tall, strong, healthy growth. Leaflets broad, pointed; tendrils green; no axillary color shown.

Comparison — A deeper color than Katherine Tracy, but otherwise similar. Bridesmaid was an improvement on Princess Beatrice.

CROWN PRINCESS OF PRUSSIA

Originated by ————. *Introduced by* Haage & Schmidt, 1868–1869.

Donated by Morse, for evolution studies.

Description in brief — Light rose, shading deeper toward center.

Description in detail — Color of standard shading from mauve-rose 153 (1) to rosy white 8 (1); wings mauve-rose 153 (1); color is deeper at base of standard and on dorsal edges of wings. Flower small, open form; standard small, badly reflexed, with notched top; wings long and narrow, partly open. Flowers two to three, on long stems of medium strength. Moderately fragrant. Moderately but continuously productive. Burns badly. Plant of medium height and slender growth. Leaflets narrow and pointed; tendrils green.

Comparison — Colors weaker than those of Peach Blossom.

Remarks — Catalogued by C. Platz, of Erfurt, in 1870. Distributed in England by Sharpe in 1871. Probably the first of the pink varieties.

DUCHESS OF MARLBORO

Originated by ————. *Introduced by* May, 1894.

Description in brief — " A rich rose color."— May's catalogue.

Description in detail — In Bulletin 111 of this station the variety is described as follows: " Flowers small. Standard flat. Color, standard pink, wings rose-pink. Bloom profuse."

Remarks — A colored illustration of this variety appeared on the back cover of May's catalogue for 1895.

DUKE OF KENT

Originated by ————. *Introduced by* May, 1894.

Description in detail — In Bulletin 111 of this station is the following description of this variety: " Flowers small. Standard flat, wedge-shape. Color, rose-pink. Bloom medium."

Remarks — Introducer gives color as a beautiful carmine.

ISA ECKFORD

Originated by Eckford. *Introduced by* Eckford, 1887.

Description in brief — Creamy white, suffused with rosy pink.

Comparison — Peach Blossom is the larger form of this variety. Crown Princess of Prussia is somewhat similar.

KATHERINE TRACY

Originated by Ferry. *Introduced by* Ferry, 1895.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — A soft pink, with lighter edges.

Description in detail — Color of standard mauve-rose 153 (1), center 153 (4); wings mauve-rose 153 (2). Flower of medium size, open form; standard of medium size, flat, with notched top; wings of medium size, short, partly open. Flowers two, on medium stems. Fragrant. Bloom profuse. A garden variety. Plant of tall, strong, healthy growth. Leaflets broad, pointed; tendrils green; no axillary color shown.

Remarks — One of the most famous American varieties.

PEACH BLOSSOM

Originated by Eckford. *Introduced by* Eckford, 1893.

Donated by Morse, for evolution studies.

Description in brief — Deep pink, shading to light pink on edges.

Description in detail — Color of standard shades from mauve-rose 153 (2) in center near base, to rosy white 8 (2–3) at edges; wings mauve-rose 153 (1), becoming lighter at edges; the early stage of development of the flower shows a trace of yellow; the general effect is a beautiful pink. Flower medium to large, open form; standard medium to large, flat, with notched top; wings long and narrow, concealing the keel. Flowers two, on medium stems. Very fragrant. Bloom profuse, continuous. Burns slightly. Plant of medium height. Leaflets narrow, pointed, dark green; tendrils colored.

Comparison — Lovely is the improved form of this variety.

PRINCESS BEATRICE

Originated by Muskett. *Introduced by* C. C. Hurst & Son, 1883.

Description in brief — Standard light pink, wings light rose-pink.

Comparison — Carmine Rose is similar.

Remarks — Given award by Royal Horticultural Society in August, 1883.

Salmon Shades

HENRY ECKFORD

Originated by Eckford. *Introduced by* Eckford, 1906.

Donated by Boddington, Rawson, 1910; Burpee, 1911.

Description in brief — A beautiful salmon color.

Description in detail — Color of standard shrimp pink 75 (2); wings shrimp pink 75 (2–3). Flower above medium size, open form; standard of medium size, flat, with round top; wings short and broad, partly open. Bloom profuse. Moderately fragrant. Burns very badly. Stems strong, but of medium length. A garden variety. Plant of medium height and strong growth. Leaflets narrow, pointed; pedicels red.

Striped and Flaked (Orange-rose group)

CORONET

Originated by S. T. Walker. *Introduced by* Walker, W. T. Hutchins, 1898.
Donated by Morse, for evolution studies.
Description in brief — Light orange-pink stripe on a white ground.
Description in detail — Standard and wings striped with peach-blossom 127 (standard 3–4, wings 1–2) on a rosy white 8 (4) ground. Flower large, open form; standard large, flat, with notched top; wings long and broad, concealing the keel. Flowers on slender stems of medium length. Moderately fragrant. Moderately productive. Plant of medium height and slender growth. Leaflets narrow, pointed.
Comparison — Aurora is superior.

Striped and Flaked (Pink-on-primrose group)

ELFRIEDA

Originated by ————. *Introduced by* W. W. Johnson & Son, 1904.
Description in brief — Slightly striped with rose on a primrose ground.

Striped and Flaked (Purple and Blue group)

HESTER

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1908.
Donated by Rawson, 1910; Burpee, 1911.
Description in brief — A deep blue stripe on white.
Description in detail — Ground color of standard and wings purplish-tinted white, striped with violet-purple 192 (1–2). Flower of medium size, open form; standard of medium size, erect, with round top; wings long and broad, partly open. Flowers two to three, on medium stems. Fragrant. Bloom profuse. Growth strong, vigorous.
Comparison — Prince Olaf is superior.

MARBLED BLUE

Originated by Sutton & Sons. *Introduced by* Sutton, 1906.
Description in brief — White, striped with blue.
Comparison — Similar to Hester.

PRINCE OLAF

Originated by Dobbie. *Introduced by* Dobbie, 1908.
Donated by Dobbie.
Description in brief — White, striped with blue.
Description in detail — Color of standard and wings purplish-tinted white, striped with lobelia-blue 205 (3); wings 205 (1). Flower of medium size or larger; standard of

medium size, slightly reflexed at times; wings long and broad, partly open. Flowers usually three, on long, strong stems. Moderately fragrant. Bloom profuse, continuous. Pedicels blackish. Suitable for home decoration.
Comparison — Has a trifle more red in the flowers than Hester.
Remarks — The best variety in this color and class.

PURPLE BROWN STRIPE

Donated by Morse, for evolution studies.
Description in brief — A white variety, striped with maroon on standard and with violet on wings.
Description in detail — Ground color rosy white 8 (4); standard striped with dark violet 193 (3–4), wings with bright violet-purple. Flower of medium size; standard of medium size, flat, with narrow base and notched top; wings long and broad, partly open. Flowers two to three, usually two, on long, strong stems. Fragrant. Bloom moderately profuse, but continuous.
Synonyms — A variety named Black Brown Striped proved to be the same. Light Blue and Purple Striped White is the same variety.

Striped Red and Rose (Crimson-on-white group)

AMERICA

Originated by Morse. *Introduced by* Vaughan, 1896.
Donated by Morse, Vaughan, 1910; Burpee, 1911.
Description in brief — A carmine stripe on white.
Description in detail — Standard and wings striped with carmine-red on a very white ground. Flower medium to large, open form; standard medium to large, flat; wings long. Flowers two to three, on long, wiry stems. Very fragrant. Bloom profuse, continuous. Plant of medium height and slender growth. Leaflets narrow, pointed; pedicels red.
Comparison — Distinct from Queen of the Isles.
Remarks — The brightest red-striped variety. Name originally proposed was Toreador.

COLUMBIA

Originated by Hutchins. *Introduced by* Hutchins, 1897.
Donated by Morse.
Description in brief — Standard light crimson, wings lavender, striped on white.

DAYBREAK

Originated by Hutchins. *Introduced by* Burpee, 1896.
Donated by Morse, for evolution studies.
Description in brief — White, striped with carmine; wings striped with rose.
Description in detail — Color of standard carmine-purple 156 (2) striped and grained on white, back carmine-purple in center with lighter edges; wings white, with markings of violet-rose 154 (1). Flower of medium size, open form; standard of medium size, flat, with notched top and narrow base; wings long and narrow, partly open. Flowers two to three, on long, strong stems. Bloom profuse, continuous. Plant of medium height and slender growth. Leaves narrow, pointed.

INVINCIBLE SCARLET STRIPED

Description in brief — Red-striped on a white ground.

INVINCIBLE STRIPED

Originated by ——————. *Introduced by* Carter, 1880.

Description in brief — Striped with crimson on a white ground.

Description in detail — In Bulletin 111 of this station the following description of this variety appears: "Flowers medium size. Standard slightly convex, notched. Color, white streaked with pink, rather cheap. Bloom profuse."

Remarks — Awarded a First Class Certificate by the Royal Horticultural Society on August 22, 1883.

QUEEN OF THE ISLES

Originated by Eckford. *Introduced by* Eckford, 1885.

Donated by Morse, for evolution studies.

Description in brief — White, striped with carmine-purple.

Description in detail — Standard striped with carmine-purple 156 (2–3) on a rosy white 8 (3–4) ground; wings striped with solferino-red 157 (1) on a rosy white ground. Flower of medium size, open form; standard of medium size, reflexed, with notched top and narrow base; wings long and narrow. Flowers two, on short or medium stems of only moderate strength. Bloom moderate. Plant of medium height, slender. Leaflets narrow, pointed; tendrils green.

Comparison — Queen of the Isles has more purple in the stripes of the wings, and less intense red in the stripes of the standard, than is found in America. America is a self, Queen of the Isles is not.

RED AND WHITE STRIPED

Description in detail — In Bulletin 111 of this station the variety is described as follows: "Flowers medium size. Standard convex. Color white strongly streaked with pink. Bloom sparse."

Comparison — This variety was superseded by America.

Synonyms — "Is Scarlet Striped."— Bulletin 127 of this station.

Striped Red and Rose (Pink-on-white group)

BERTIE HAMILTON

Originated by Walker. *Introduced by* Walker, 1898.

Description in brief — Lightly striped with dark ox blood on front of standard and wings, and more heavily striped on reverse.

DUCHESS OF YORK

Originated by Eckford. *Introduced by* Eckford, 1894.

Donated by Morse, for evolution studies.

Description in brief — A light pink stripe on white.

Description in detail — Standard and wings striped with pale lilac-rose 130 (2) on a lilacy white 7 (1) ground. Flower medium to large, open form; standard medium to large, flat; wings long and narrow, concealing the keel. Flowers borne on medium stems. Very fragrant. Bloom profuse, continuous. Plant of medium height and slender growth. Leaflets narrow, pointed; tendrils colored.

Comparison — Ramona is similar in color but is of hooded form.

MINNEHAHA

Originated by Walker. *Introduced by* Peter Henderson & Co., 1898.

Description in brief — Striped with pale pink.

White

ALBA MAGNIFICA

Originated by Henderson. *Introduced by* Henderson, 1891.

Donated by Morse, for evolution studies.

Description in brief — A small, white variety.

Description in detail — Color milk white 11 (2–3). Flower small, open form, with notched standard and narrow base.

Comparison — An improvement on Queen of England, but superseded in its turn by Emily Henderson.

EARLIEST WHITE

Originated by Gould. *Introduced by* Burpee, 1906.

Donated by Boddington, Burpee.

Description in brief — A very early, white variety.

Description in detail — Color milk white 11 (2–3); wings and standard have no trace of color except in the young bud. Flower of medium size, open form; standard notched; wings long and broad. Substance good. Flowers one to three, on short to medium stems. Fragrant. Plant dwarf. Leaflets dark green, narrow, pointed. Seed large, round, black.

Remarks — This variety properly belongs to the winter-flowering type, but is also grown in gardens. Valuable only for very early flowers.

EMILY HENDERSON

Originated by ————. *Introduced by* Henderson, 1893.

Description in brief — A medium-sized, white variety.

Description in detail — Flower of medium size, open form; standard with notched top and narrow base, inclined to curve back at the sides. Flowers borne on slender stems of moderate length, appearing to be far apart on the stems. Easily injured by wet weather. Plant slender, but tall.

Remarks — No longer of any value. For ten years the standard white variety

GRACE MAY

Originated by ————. *Introduced by* May, 1894.

Description in detail —"A magnificent large flowering white sweet pea. The individual flowers often measure two and one half inches in diameter and waxy white color and highly perfumed."—May's catalogue, 1894.

JOSEPHINE WHITE

Originated by Ferry. *Introduced by* Ferry, 1902.

Description in brief — A white variety.

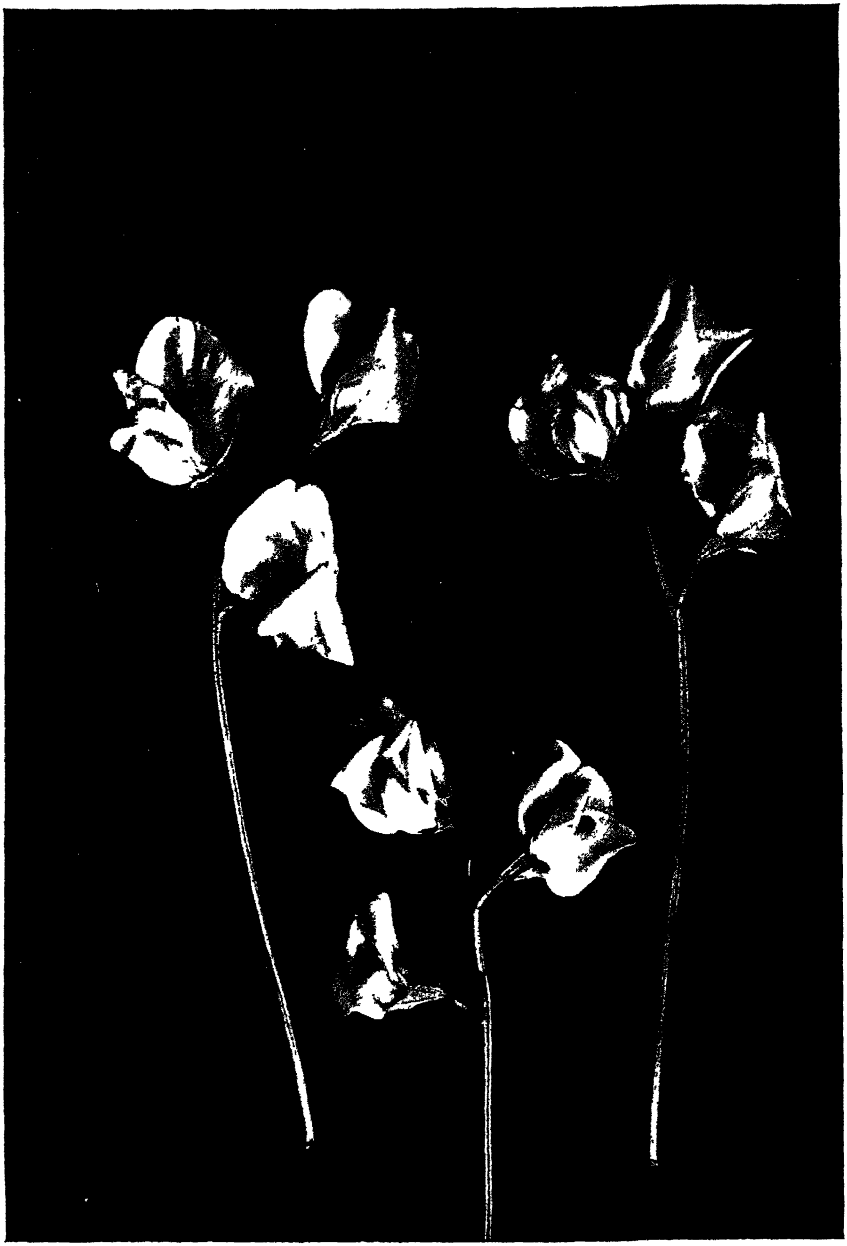
MRS. LANGTRY

Originated by ————. *Introduced by* May, 1894.

Description in brief — "A charming white."— Introducer's description, 1894.

Description in detail — " Flowers medium size. Standard flat. notched. Color, pure white. rich. Bloom medium."— Bulletin 111 of this station.

Queen of England *Alba Magnifica*



Janet Scott

MONT BLANC

Originated by Ernest Benary(?). *Introduced by* Benary, 1900.

Donated by Boddington, 1910.

Description in brief — An early, pure white variety.

Description in detail — Color of standard and wings creamy white 10 (1). Flower of medium size, open form; standard of medium size, flat, notched; wings of medium size, spreading. Plant slender, of dwarf growth. Leaflets narrow, pointed. Seed white.

Comparison — Not so early as Earliest of All, which also has the advantage of black seeds, giving better germination in cold soil early in the spring.

Remarks — Belongs properly to the winter-flowering type, but is grown in gardens for early bloom.

QUEEN OF ENGLAND

Originated by Eckford. *Introduced by* Eckford, 1888.

Donated by Morse, for evolution studies.

Description in brief — A small, white variety.

Description in detail — Flower small, open form; standard notched at top, often at sides, and with a narrow base. Flowers two to three, on slender stems of medium length. Plant of tall, vigorous growth.

Comparison — Superseded by Alba Magnifica and Emily Henderson.

SHASTA

Originated by Morse. *Introduced by* Morse, 1904.

Donated by Boddington, Rawson, 1910; Burpee, 1911.

Description in brief — A large, pure white flower, of open form.

Description in detail — Color 2 (1), opens light primrose, changing to pure white. Flower large, open form; standard large, generally showing a slight notch and a trace of waviness; wings of medium size. Flowers usually three, on long, strong stems. Fragrant. Plant of tall, very strong growth.

SNOWFLAKE

Originated by S. Fisher. *Introduced by* Breck, 1897.

Description in brief — A pure white.

Remarks — One of the first varieties to receive a first-class certificate from an American horticultural society, having received this award from the Massachusetts Horticultural Society in 1893.

WHITE TRIUMPH

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1908.

Description in brief — " A large, expanded white."— Introducer's catalogue.

Comparison — A white form of Triumph.

ZERO

Originated by Biffen. *Introduced by* Miss Hemus, 1907.

Donated by Miss Hemus, 1910.

Description in brief — An early, pure white variety.

Yellow Shades

DEVONSHIRE CREAM

Originated by Bathurst. *Introduced by* G. H. Mackereth, 1908.

Description in brief — A large, primrose variety.

Comparison — Said to be like Shasta in primrose color. Introduced as an improved form of The Honorable Mrs. E. Kenyon.

EARLIEST SUNBEAMS

Originated by Morse. *Introduced by* Burpee, 1904.

Donated by Boddington.

Description in brief — An early-flowering, primrose variety.

Description in detail — Color of standard yellowish white 13 (1–2), back a deeper shade; wings a slightly lighter color. Flower open form; standard notched; wings long and broad. Substance good. Flowers one to three, on medium stems. Moderately fragrant. Bloom early and free. Plant of short height. Leaflets dark green, narrow, pointed. Seed white.

Remarks — Properly belongs to the winter-flowering type. Sometimes planted with Earliest White and Earliest of All for very early bloom.

HAROLD

Originated by Isaac House & Sons. *Introduced by* House, 1910.

Description in brief — A primrose variety.

Comparison — Said to be a cream-colored Shasta.

INCONSTANCY

Originated by Ferry. *Introduced by* Ferry, 1902.

Donated by Morse, for evolution studies.

Description in brief — A yellow and white variety.

Description in detail — Color of standard and wings creamy white 10 (standard 3–4, wings 1–2); the standard fades to 10 (1); the general effect is of yellow and white flowers on the same plant, hence the name. Flower of medium size, open form; standard of medium size, flat, with notched top; wings long and broad, partly open. Flowers on strong stems of medium length. Bloom profuse, continuous. Plant of medium height and slender, healthy growth. Leaflets narrow, pointed; tendrils green. Seed white.

PRIMROSE

Originated by Eckford. *Introduced by* Eckford, 1889.

Description in brief — A light primrose self, of medium size and open form.

Comparison — Golden Gleam, Mrs. Eckford, and similar varieties, are larger, finer varieties of this shade.

HOODED VARIETIES

Bicolor

AMERICAN BELLE

Originated by ———————. *Introduced by* Burpee, 1894.

Description in brief — " Standard bright rose; wings crystal white, with purplish carmine spots."— Introducer's description.

Synonyms — In Bulletin 127 of this station American Belle is said to be Apple Blossom.

APPLE BLOSSOM

Originated by Eckford. *Introduced by* Eckford, 1888.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — Standard rose-pink; wings white, tinged with pink.

Description in detail — Color of standard violet-rose 154 (4) in the center, with lighter edges; wings pale pink 135 (1). Flower of medium size, hooded form; standard of medium size, hooded, with round top; wings long and narrow, concealing the keel. Flowers two to three, on good stems. Very fragrant. Bloom profuse, continuous. Plant of medium growth. Leaflets dark green, narrow, pointed.

Comparison — Has greater contrast between standard and wings than is shown in Royal Rose.

Remarks — Very variable in color.

COQUETTE

Originated by Eckford. *Introduced by* Eckford, 1896.

Description in brief — Standard shaded with lavender on a primrose ground; wings primrose.

CROWN JEWEL

Originated by Eckford. *Introduced by* Eckford, 1896.

Description in brief — Tinted and veined with violet-rose on a primrose ground.

DAWN

Originated by G. Stark & Son. *Introduced by* Stark.

Description in brief — Standard light crimson-magenta; wings white, shaded crimson.

EMILY LYNCH

Originated by Lynch. *Introduced by* Lynch, 1897.

Donated by Morse, for evolution studies.

Description in brief — Standard rose; wings rose on a primrose ground.

Description in detail — Color of standard violet-rose 154 (4); wings mauve-rose 153 (1) on a primrose-tinted ground. Flower small to medium, hooded form; standard small to medium, hooded, with notched top and sides; wings short and broad, partly open. Flowers two, on short or medium stems. Very fragrant. Bloom profuse, continuous. Burns slightly in hot sunshine. Plant of medium height and slender growth. Leaflets narrow, pointed; tendrils colored at first, changing to green.

Comparison — Superseded by Jeannie Gordon.

Remarks — One of the first of the Apple Blossom group.

HILDA JEFFREY

Originated by C. W. Breadmore. *Introduced by* Breadmore, 1908.

Description in brief — " Delicate rose shaded cream."— Gardener's World, 1908, page 82.

Comparison — Is said to be an improvement on Jeannie Gordon.

JEANNIE GORDON

Originated by Eckford. *Introduced by* Eckford, 1902.

Donated by Boddington, Burpee.

Description in brief — A bright rose on a cream ground.

Description in detail — Color of standard deep rose-pink 120 (1–2); wings rosy pink 118 (1) on a primrosy ground; base of standard often has a trace of primrose color. Flower medium large, hooded; standard medium large, hooded, with round top; wings long and broad, partly open. Flowers two to three, irregularly placed on long, strong stems. Moderate fragrance. Bloom profuse, continuous. Plant of medium height and strong growth. Leaflets narrow, pointed; tendrils green.

Comparison — Emily Lynch is very similar in color, but is smaller.

Remarks — The best of the old type in this color.

LADY SKELMERSDALE

Originated by Eckford. *Introduced by* Eckford, 1899.

Description in brief — "Standard bright rosy lilac; wings slightly shaded bright rosy lilac."— Burpee's catalogue.

MRS. E. GILMAN

Originated by Eckford. *Introduced by* Eckford, 1910.

Description in brief — A pale rose bicolor.

ROYAL ROSE

Originated by Eckford. *Introduced by* Eckford, 1896.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — Standard pink; wings rose, with lighter edges.

Description in detail — Color of standard violet-rose 154 (4), back 155 (1–2); wings violet-rose 154 (1–2). Flower large, hooded; standard large, hooded, with round top; wings long and broad, partly open. Flowers two to three, on long, strong stems. Very fragrant. Bloom profuse, continuous. Plant of tall, strong growth.

Comparison — The waved form of this variety is Apple Blossom Spencer.

TWEEDY SMITH

Originated by Breadmore. *Introduced by* Breadmore, 1907.

Description in brief — "Standard light magenta lilac; wings light cream."— Morse's Field Notes on Sweet Peas.

Blue and Purple Shades (Bright Blue group)

ENID

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1909.

Donated by Miss Hemus, 1910.

Description in brief — A deep blue variety.

Description in detail — Color of standard and wings aniline blue 202 (1–2); wings deeper than standard. Flower of medium size, hooded form; standard of medium size, slightly hooded, with round top; wings long and narrow, partly open. Flowers two, on medium stems. Very fragrant. Sunproof. Suitable for home decoration. Plant of medium height, slender, healthy. Tendrils green. Seed round, mottled.

Comparison — The general effect is lighter than Eileen and deeper than Flora Norton.

Blue and Purple Shades (Purple standard, blue wings)

CAPTAIN OF THE BLUES

Originated by Eckford. *Introduced by* Eckford, 1889.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — Standard bright violet-purple, wings lavender-blue.

Description in detail — Color of standard bright violet-purple 190 (3–4); wings lavender-blue 204 (1–2). Flower of medium size, hooded form; standard of medium size, slightly hooded, with round top; wings of medium size, broad, partly open. Flowers three, equidistant on long, strong stems. Very fragrant. Bloom profuse. continuous. Plant tall, of moderately strong growth. Leaflets narrow, pointed,

Comparison — Imperial Blue is an inferior form of this. Baden Powell is considered to be the same.

Remarks — Offered in the United States by Farquhar in 1891.

COUNTESS CADOGAN

Originated by Eckford. *Introduced by* Eckford, 1899.

Donated by Boddington, 1910; Burpee, 1911

Description in brief — Standard bluish purple, wings blue.

Description in detail — Color of standard bright violet-purple 190 (2), becoming more blue at the base, back violet-purple 192 (2); wings bluish violet 203 (1), losing the purple shading, becoming light blue, back 203 (4). Flower large, hooded form; standard large, hooded, with round top; wings long and broad, partly open. Flowers two to three, usually two, on medium stems. Plant of tall, strong growth. Tendrils show some color.

DAVID R. WILLIAMSON

Originated by Eckford. *Introduced by* Eckford, 1905.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — Standard bluish purple, wings lavender-blue.

Description in detail — Color of standard bright violet-purple 190 (2), back 192 (2); wings lavender-blue 204 (2); keel same as wings. Flower large, hooded form; standard large, slightly hooded, with round top, wings long and broad, partly open. Flowers two to three, usually two, equidistant on long, strong stems. Very fragrant. Bloom profuse. Plant of tall, strong, healthy growth. Leaflets pointed; tendrils green.

DUKE OF WESTMINSTER

Originated by Eckford. *Introduced by* Eckford, 1900.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — Standard purple, wings blue.

Description in detail — Color of standard bishop's violet 189 (4); wings aniline blue 202 (2). Flower large, hooded form; standard large, slightly hooded, with round top; wings long and broad; keel same as wings. Flowers two to three, on long, strong stems. Very fragrant. Bloom profuse. A garden or exhibition variety. Plant of tall, strong growth. Leaflets narrow, pointed; some plants possess axillary color.

Remarks — One of the best of the old varieties.

IMPERIAL BLUE

Originated by Eckford. *Introduced by* Eckford, 1887.

Donated by Morse, for evolution studies.

Description in brief — Standard purple, wings light blue.

Description in detail — Color of standard rich pansy-violet 192 (1–2), back 191 (4); wings bishop's violet 189 (4), shaded lavender-blue 204 (1). Flower of medium size, hooded form; standard of medium size, hooded, with notched sides; wings long and narrow. Bloom profuse.

Comparison — Captain of the Blues is a large, improved form of this variation.

Synonyms — Madam Carnot is said to be the same variety. Grand Blue is the same.

MADAME CARNOT

Originated by Laxton. *Introduced by* Laxton, 1892.

Description in brief — A small, inferior form of Captain of the Blues

Synonyms — Morse states that Imperial Blue is the same variety.

WAVERLY

Originated by Eckford. *Introduced by* Eckford.

Description in brief — Standard purple, wings blue.

Comparison — Duke of Westminster is similar but larger.

Blue and Purple Shades (Violet and Indigo group)

BRILLIANT BLUE

Originated by ——————. *Introduced by* Burpee, 1907.

Description in brief — A dark navy blue variety.

Description in detail — Color of standard bluish violet 203 (4–5); wings light bluish violet 202 (4), changing to bluish violet 203 (4). Flower large, hooded form; standard large, slightly hooded, with round top; wings medium broad, partly open to spreading. Flowers two to three, usually three, on strong stems of medium length. Bloom profuse. Plant of tall, strong growth.

Synonyms — Same as Lord Nelson (House, 1907).

Remarks — The best dark blue of the old type.

LORD NELSON

Originated by House. *Introduced by* House, 1907.

Donated by Boddington, 1910.

Description in brief — A dark navy blue variety.

Description in detail — (See description of Brilliant Blue.)

Synonyms — This is the name used in Great Britain for Brilliant Blue.

NAVY BLUE

Originated by James Sproule. *Introduced by* Burpee, 1899.

Description in brief — General effect is dark blue; standard lavender-blue, wings bluish violet.

Description in detail — Color of standard lavender-blue 204 (4–5); wings bluish violet 203 (4), becoming slightly more purple. Flower medium to large, hooded form; standard medium large, slightly hooded, sometimes slightly notched at top; wings

broad and moderately long, partly open. Flowers two to three, equidistant on strong stems of medium length. Moderately fragrant. Plant of tall, strong growth. Leaflets pointed; tendrils green; no axillary color.

Blush

ACME

Originated by ——————. *Introduced by* Jones, 1908.

Description in brief — A blush-white variety.

Comparison — Said to be a blush Dorothy Eckford.

AGNES ECKFORD

Originated by Eckford. *Introduced by* Eckford, 1907.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — A very light pink self.

Description in detail — Color of standard and wings mauve-rose 153 (1–2). Flower above medium size, hooded form; standard above medium size, hooded, with round top; wings long and partly open. Flowers three, equidistant on long stems. Very fragrant. Plant of tall, strong growth. Leaflets narrow, pointed; tendrils colored at first, becoming green when fully developed; axillary color in peduncles and leaflets.

Comparison — Larger and better than California.

BLUSHING BEAUTY

Originated by Eckford. *Introduced by* Eckford, 1893.

Donated by Burpee, 1910.

Description in brief — Medium size, light pink.

Description in detail — Color of standard and wings mauve-rose 153 (1); standard becomes paler at the edges. Flower of medium size, hooded form; standard of medium size, extremely hooded, without apical notch; wings of medium size but long, partly open. Flowers usually two, on long stems of moderate strength. Moderately productive. Plant of tall, strong growth.

Comparison — California is similar, but is lighter in color. Royal Robe is similar, but darker. Prima Donna is darker, larger, and superior in every respect.

CALIFORNIA

Originated by Lynch. *Introduced by* Lynch, 1897.

Donated by Morse, 1910.

Description in brief — A small, very light pink variety.

Description in detail — Color of standard pale rosy pink 129 (1–2); wings lilacy white 7 (4). Flower small, hooded form; standard small, much hooded, often curled; wings of medium size, long, partly open. Flowers usually two, on long stems of moderate strength. Moderately productive. Plant of tall, strong growth.

Comparison — Agnes Eckford is much superior. Blushing Beauty is similar, but darker.

COTTAGE MAID

Originated by ——————. *Introduced by* Sutton.

Description in brief — Pale blush on white.

COUNTESS OF ABERDEEN

Originated by Eckford. *Introduced by* Eckford, 1895.
Description in brief — A pale pink variety.

DELICATA

Originated by ————. *Introduced by* Stark, 1906.
Description in brief — White, tinted pink.
Synonyms — Considered same as Modesty.

DUCHESS OF SUTHERLAND

Originated by Eckford. *Introduced by* Eckford, 1898.
Description in brief — Silvery white, tinted pink.
Synonyms — Same as Modesty.

EVELYN BREADMORE

Originated by Breadmore. *Introduced by* Breadmore, 1906.
Description in brief — Shining white, with slight tinge of pink in standard.

LADY ABERDARE

Originated by ————. *Introduced by* Breadmore, 1904.
Description in brief — " Soft light pink self."— Sweet Pea Annual.

MRS. S. T. WALKER

Originated by Walker. *Introduced by* Walker, 1898.
Description in brief — Pale blush-pink, hooded.

MODESTY

Originated by Morse. *Introduced by* Burpee, 1898.
Donated by Burpee, 1911.
Description in brief — Silvery white, tinted pink.

SENSATION

Originated by Morse. *Introduced by* Burpee, 1898.
Description in brief — Standard very light pink and buff; wings white.
Comparison — A hooded Alice Eckford.

Carmine and Rose (Carmine group)

COLONIST

Originated by Eckford. *Introduced by* Eckford, 1898.
Description in brief — A bright rose-crimson, changing to purplish crimson.

MRS. DUGDALE

Originated by Eckford. *Introduced by* Eckford, 1899.
Donated by Burpee, 1911.
Description in brief — Large, slightly hooded, crimson-rose on a primrose ground.
Description in detail — Flower large, hooded; standard large, slightly hooded; wings large, long and broad.

MRS. R. M. SHELTON

Originated by ———————. *Introduced by* Bakers, 1909.
Description in brief — A hooded, rosy carmine self.

Carmine and Rose (Rose group)

BRITISH QUEEN

Originated by Angus. *Introduced by* ———————.
Description in brief — A double form of Her Majesty.
Remarks — This was shown by Mr. Angus, Norwood Hall, Aberdeen, and received a First Class Certificate from the Royal Caledonian Horticultural Society in 1898.

CYRIL BREADMORE

Originated by Breadmore. *Introduced by* Breadmore, 1906.
Description in brief — A slightly hooded, rosy carmine variety.
Synonyms — Practically the same as Lord Roseberry.

ESMERALDA

Originated by ———————. *Introduced by* Kelway & Son.
Description in brief — " A distinct shade of rose."— Kelway Manual, 1911.

HER MAJESTY

Originated by Eckford. *Introduced by* Eckford, 1892.
Description in brief — Large, hooded, rose-crimson self.

MAJESTIC

Originated by Morse. *Introduced by* Burpee, 1901.
Description in brief — Large, hooded, rose-red on a primrose ground.

ODDITY

Originated by Morse. *Introduced by* Burpee, 1896.
Donated by Morse, for evolution studies.
Description in brief — Deep pink, with deeper edges; wings lighter pink.
Description in detail — Color of standard violet-rose 154 (3–4); wings violet-rose 154 (1). Flower of medium size; standard of medium size, reflexed or crumpled, with notched sides; wings long and narrow, some wings twisted or curled, concealing the keel. Many flowers are double. Flowers two or three, irregularly placed on long stems of medium strength. Bloom profuse, continuous. Burns slightly. Plant of slender growth. Leaflets narrow, pointed; tendrils green.
Remarks — Name given because of the form of the flowers; expresses value also.

OVID

Originated by Eckford. *Introduced by* Eckford, 1893.
Donated by Morse, for evolution studies.
Description in brief — Standard purple-rose, wings violet-rose.
Description in detail — Color of standard purple-rose 150 (1–2); wings violet-rose 154 (1), back a deeper color; well-matured flowers are very bright. Flower of medium size, hooded form; standard of medium size, hooded, wings long and broad, con-

cealing the keel. Flowers two, on medium stems. No apparent fragrance. Bloom profuse, continuous. Burns slightly in very hot sunshine. Plant of medium height and slender growth. Leaflets narrow, pointed.

Comparison — Novelty and Miss Hunt are the same color, but are smaller and open form.

PRINCE OF WALES

Originated by Eckford. *Introduced by* Eckford, 1898.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — A large, hooded, rose-crimson variety.

Description in detail — Color of standard and wings violet-rose 154 (4–5). Flower large, hooded form; standard large, slightly hooded; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Fragrance none. Bloom profuse, continuous. A garden variety. Plant of tall, stout, vigorous, healthy growth. Color sometimes shown in axils of leaves and tendrils.

Comparison — Her Majesty and Splendour are smaller and less bright.

Remarks — Represents the greatest advance made in the hooded varieties of this color.

SPLENDOUR

Originated by Eckford. *Introduced by* Eckford, 1888.

Donated by Morse, for evolution studies.

Description in brief — A large, hooded, rose-crimson variety.

Description in detail — Color of standard Tyrian rose 155 (1); wings Tyrian rose 155 (1–2). Flower large, hooded form; standard large, hooded, with round and looped top; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Very fragrant. Bloom profuse, continuous. Sunproof. Plant of medium height and slender growth. Leaflets narrow, pointed, dark green; tendrils colored.

Cerise

ANNIE B. GILROY

Originated by Eckford. *Introduced by* Eckford, 1909.

Description in brief — " A deep cerise."— Sweet Pea Annual.

Comparison — Introduced as an improved Coccinea.

Remarks — No longer catalogued by the introducer.

COCCINEA

Originated by Eckford. *Introduced by* Eckford, 1901.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — A bright cerise self.

Description in detail — Color of standard and wings crimson-red 114 (1). Flower below medium size, hooded; standard of medium size, slightly hooded, with round top; wings long and narrow, concealing the keel. Moderately fragrant. Bloom profuse, continuous. Flowers two to three, usually two. Burns badly. Plant of medium height and slender growth. Leaflets narrow, pointed, blue-green; tendrils short, colored. Habit distinct.

PRINCESS MAUD OF WALES

Originated by Eckford. *Introduced by* Eckford, 1906.

Description in brief — " A pale coccinea."—Sweet Pea Annual.

Remarks — No longer catalogued by the originator.

Cream-Pink

CORAL GEM

Originated by Tuttle. *Introduced by* Vaughan, 1907.

Donated by Vaughan, 1910.

Description in brief — A soft, light cream-pink.

Description in detail — Color of standard and wings mauve-rose 153 (1–2); center stripe of standard 153 (4). Flower of medium size; standard of medium size, hooded, with round top; wings long and broad. Very fragrant. Bloom profuse.

COUNTESS OF LATHOM

Originated by Eckford. *Introduced by* Eckford, 1900.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — A cream-pink self.

Description in detail — Color of standard mauve-rose 153 (2); wings mauve-rose 153 (1–2); both on a primrose ground. Flower of medium size, hooded form; standard of medium size, hooded, with round top; wings broad, partially spreading. Flowers two to three, borne on long stems of medium strength. Moderately fragrant. A moderately productive variety. Plant of tall, vigorous growth. Tendrils green.

Comparison — Color is between Venus and Honorable F. Bouverie.

GRACIE GREENWOOD

Originated by Eckford. *Introduced by* Eckford, 1902.

Description in brief — A slightly hooded flower; cream, shaded delicate pink.

G. W. KERR

Originated by ————. *Introduced by* Bakers, 1910.

Description in brief — Coral-pink, deeper shade on edge.

HONORABLE F. BOUVERIE

Originated by Eckford. *Introduced by* Eckford, 1899.

Donated by Morse, 1910.

Description in brief — A deep pink on a primrose ground. The edges are very light pink, the color deepening toward the center.

Description in detail — Color of standard and wings mauve-rose 153 (1–3) on a creamy white 10 (3–4) ground. Flower of medium size, hooded form; standard of medium size, slightly hooded, with round top; wings short and narrow, partly open. Flowers three, equidistant on long stems. Very fragrant. Bloom profuse. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Comparison — Is Lovely on a primrose ground.

JANET SCOTT

Originated by Morse. *Introduced by* Burpee, 1903.

Donated by Boddington, Burpee, 1910.

Description in brief — Bright pink, tinged with buff.

Description in detail — Color of wings and standard mauve-rose 153 (2–3); standard shows traces of yellow, which is more pronounced in the upper flower as well as in the bud. Flower large, hooded form; standard large, hooded, with round top;

wings long, upright, and pointed. Flowers two to three, usually three, equidistant on long, strong stems. Moderately fragrant. Plant of tall, strong growth. Leaflets broad, pointed; tendrils colored until mature.

Remarks — One of the best-known varieties.

MISS BOSTOCK

Originated by ———————. *Introduced by* Miss Hemus, 1907.

Description in brief — Cream-pink.

MRS. CHARLES MASTERS

Originated by Eckford. *Introduced by* Eckford, 1909.

Description in brief — " Standard rosy salmon, wings cream."— Sweet Pea Annual.

QUEEN OF SPAIN

Originated by Eckford. *Introduced by* Eckford, 1907.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — "A pearly pink self."— Sweet Pea Annual.

Description in detail — Color of standard and wings mauve-rose 153 (1). Flower of medium size, hooded form; standard of medium size, hooded, with round top; wings long and broad, spreading. Flowers two to three, on medium stems. Moderately fragrant. Bloom profuse. A fine garden variety. Plant of distinct character; growth strong and vigorous. Tendrils profusely colored; color in axils of peduncles, leaves, and leaflets; flower stems also tinged brown.

Comparison — On the grounds at this station this variety is more productive than Countess of Lathom.

VENUS

Originated by Eckford. *Introduced by* Eckford, 1893.

Donated by Burpee, 1910, 1911.

Description in brief — A hooded variety; flowers salmon-buff, shaded pink.

Description in detail — Color of standard and wings mauve-rose 153 (1–2) on a primrose ground. Flower of medium size, hooded form; standard of medium size, hooded, with round top; wings short, partly open. Flowers two to three, on medium wiry stems. Very fragrant. Plant of tall, slender growth. Tendrils green.

Remarks — As the season advances, the flowers have more pink color.

Crimson and Scarlet (Crimson group)

BOB

Originated by ———————. *Introduced by* Jones, 1908.

Description in brief — " A deep red with wings tinted rose."— Sweet Pea Annual.

BRILLIANT

Originated by Morse. *Introduced by* Burpee, 1897.

Donated by Burpee.

Description in brief — A slightly hooded, crimson-scarlet variety.

Description in detail — Color of standard carmine-purple 156 (2–3); wings Tyrian rose 155 (1). Flower of medium size, slightly hooded form; standard of medium size, slightly hooded, with round top; wings long and broad, concealing the keel.

Substance poor. Flowers two to three, usually two, on medium stems. Bloom profuse and continuous. Burns badly. Plant of medium height, with slender haulms, but makes a heavy row.

Comparison — Same color as Ignea in standard, but Brilliant has less contrast in wings.

HARVARD

Originated by ————. *Introduced by* Breck, 1894.

Synonymns — In Bulletin 127 of this station this is said to be Ignea.

IGNEA

Originated by Eckford. *Introduced by* Eckford, 1892.

Donated by Morse, for evolution studies.

Description in brief — Crimson-scarlet wings, tinged with purplish crimson.

Description in detail — Color of standard carmine-purple 156 (2); wings solferino-red 157 (1). Flower of medium size, slightly hooded form; standard medium hooded, with round top and apical fold; wings long and narrow, concealing the keel. Flowers two, on strong stems of medium length. Flower burns badly, the veins soon blackening or taking on a sickly purple hue. Plant of medium height. Leaflets narrow, pointed.

MARS

Originated by Eckford. *Introduced by* Eckford, 1896.

Description in brief — A hooded, rich crimson self.

MILLIE MASLIN

Originated by Holmes. *Introduced by* Sydenham, 1908.

Donated by Burpee, 1911.

Description in brief — A very dark crimson-red.

Description in detail — Color of standard lilac-purple 160 (3–4), veined darker; wings lilac-purple 160 (1–2), often with more purple shading. Flower medium large, hooded form; standard medium to large, slightly hooded; wings long and narrow. Flowers two to three, on medium stems. Very fragrant. Bloom moderately profuse. Plant of medium height and slender growth. Leaflets narrow, pointed; tendrils green.

SALOPIAN

Originated by Eckford. *Introduced by* Eckford, 1897.

Donated by Boddington, 1910.

Description in detail — Color of standard crimson-carmine 159 (4); wings crimson-carmine 159 (2), back 159 (4). Flower of medium size, hooded form; standard of medium size, slightly hooded; wings of medium size, concealing the keel. Flowers two to three, on medium stems. Fragrance none. Bloom profuse. Sunproof. Plant of medium height and stout growth. Tendrils colored.

Comparison — This variety was superseded by King Edward VII. Salopian is a deeper, richer color, especially in the wings, than Brilliant or Mars.

Remarks — The original Salopian burned badly under a hot sun. By selection a strain was secured which exhibited little or no burning. The trial at this station was probably with this form. A pure stock.

SUNPROOF SALOPIAN

Originated by ——————. *Introduced by* Burpee, 1900.

Donated by Burpee, 1910.

Description in brief — A sunproof strain of Salopian.

Remarks — No difference was noted in the trials at this station. It is probable that the Sunproof Salopian was supplied, at least to all American customers, instead of the Salopian, owing to the fact that the latter was subject to burning under our hot suns.

Crimson and Scarlet (Scarlet group)

KESTON RED

Originated by ——————. *Introduced by* Jones, 1908.

Description in brief — A rich scarlet.

Remarks — Was introduced as an improved Scarlet Gem. Not in the trade at the present time.

QUEEN ALEXANDRA

Originated by Eckford. *Introduced by* Eckford, 1906.

Donated by Boddington, Rawson, 1910; Burpee, 1911.

Description in brief — A bright, intense, scarlet self.

Description in detail — Color of standard and wings French purple 161 (2). Flower of medium size, hooded form; standard of medium size, slightly hooded, with round top; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Plant of medium height and slender growth. Leaflets narrow, pointed.

Dark Shades (Maroon group)

ADMIRAL TOGO

Originated by Breadmore. *Introduced by* Breadmore, 1906.

Description in brief — " Extremely dark violet maroon."— Sweet Pea Annual. Flowers hooded.

BLACKBIRD

Originated by Sharpe. *Introduced by* Bolton, 1908.

Donated by Rawson, 1910.

Description in brief — A very dark maroon variety.

Description in detail — Color of standard dark purple 191 (4); wings dark purple 191 (1). Flower medium to large, hooded form; standard medium to large, hooded, with round top; wings long and broad, concealing the keel. Flowers two to three, usually two, on long, strong stems. Bloom profuse, continuous. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Synonyms — Midnight (Burpee, 1908).

BLUE BIRD

Originated by ——————. *Introduced by* Strong.

Description in brief — " Flowers medium size. Standard hooded. Color, dark purple-red. Bloom medium."— Bulletin 111 of this station.

HANNAH DALE

Originated by Dobbie. *Introduced by* Dobbie, 1908.

Donated by Dobbie, 1910.

Description in brief — A deep maroon self.

Description in detail — Color of standard and wings deep carmine-violet 174 (4). Flower large, slightly hooded form; standard above large, slightly hooded, with notched top; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Fragrance moderate. Bloom profuse, continuous. Plant of medium height and strong growth. Leaflets narrow, pointed; tendrils green.

Remarks — The flowers decrease rapidly in size.

MIDNIGHT

Originated by ——————. *Introduced by* Burpee, 1908.

Description in brief — Deep maroon and indigo.

NIGGER

Originated by House. *Introduced by* House, 1905.

Description in brief — " Nearly black."— Sweet Pea Annual.

Dark Shades (Maroon and Bronze group)

H. J. R. DIGGES

Originated by Eckford. *Introduced by* Eckford, 1908.

Description in brief — "A bright claret shaded maroon."— Eckford's catalogue.

JET

Originated by Hugh Aldersey. *Introduced by* Sydenham, 1909.

Description in brief — Standard very dark maroon; wings very dark indigo.

Synonyms — Considered the same as Midnight (Burpee, 1908).

OTHELLO

Originated by Eckford. *Introduced by* Eckford, 1899.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — A deep maroon self.

Description in detail — Back of standard dull. Flower large, hooded form; standard large, hooded, with round top; wings large, long and broad, concealing the keel. Substance good. Flowers generally three, on long, strong stems. Fragrance little or none. Plant of tall, strong, robust growth. Leaflets narrow, pointed.

SHAHZADA

Originated by Eckford. *Introduced by* Eckford, 1897.

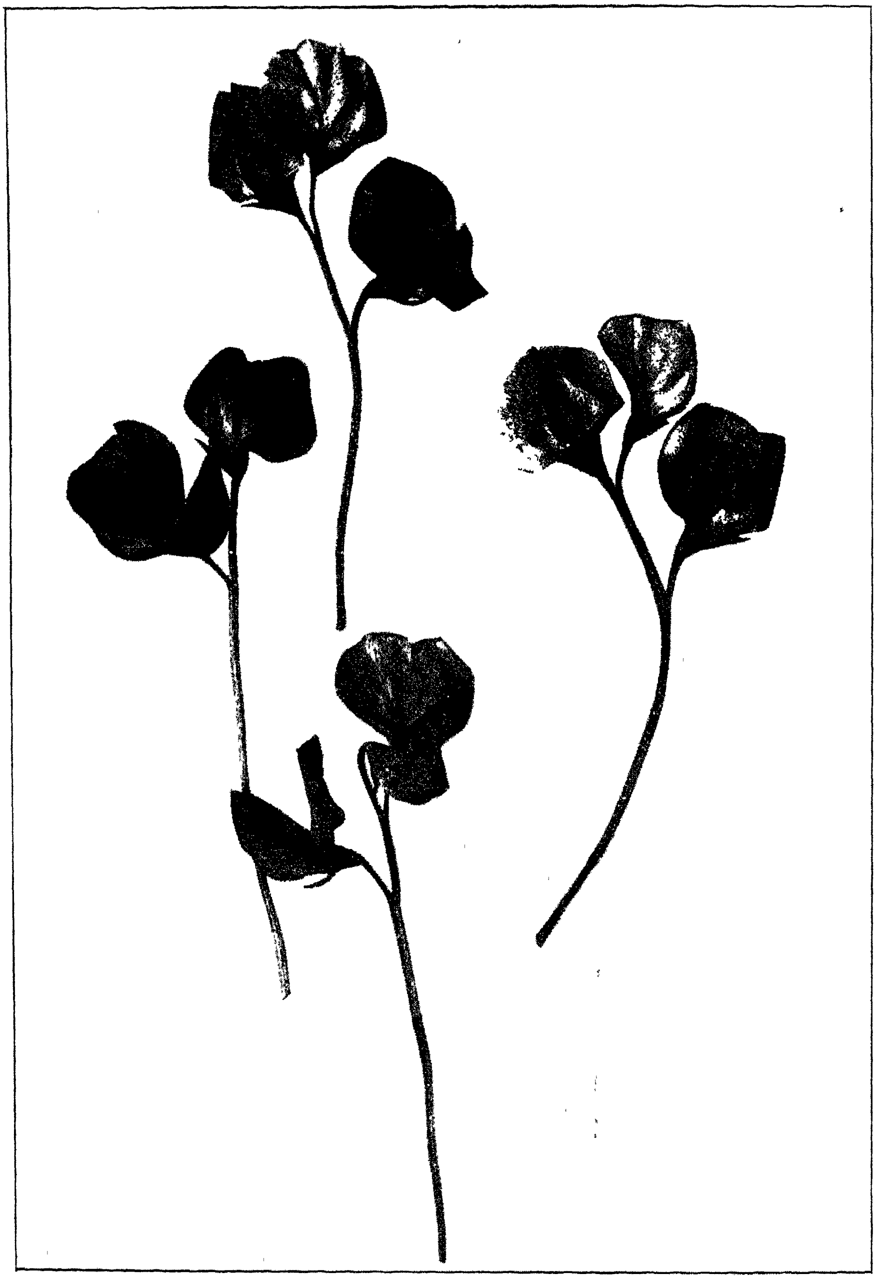
Donated by Boddington, 1910.

Description in brief — A very dark maroon and purple variety.

Description in detail — Color of standard dark purple 191 (4); wings violet-purple 192 (2–3). Flower of medium size, hooded; standard slightly hooded, with round top; wings of medium size, long, partly open. Flowers two to three, usually two, on short, weak stems.

Comparison — Has standard of the same color as Othello, but the wings are different.

Remarks — Said to be a cross between Stanley and Her Majesty.



Lord Roseberry

Comparison — Is larger and darker, and blooms better, than Black Michael. Very similar to Kelway Black. Larger than Black Knight.

Remarks — A very rich, dark-colored flower. Dudley Lees was sent out by Breadmore in 1908.

INDIGO KING

Originated by Eckford. *Introduced by* Eckford, 1886.

Donated by Morse, for evolution studies.

Description in brief — A deep violet-blue.

Description in detail —Color of standard deep carmine-violet 174 (4); wings bright violet-purple 190 (2). Flower under medium size, hooded form; standard under medium size, hooded, notched at side, wings long and narrow. Moderately productive. Plant of medium height.

Comparison — Monarch is somewhat similar in color. Horace Wright is the best variety of these colors.

Synonyms — Autocrat (Henderson, 1888) is the same variety.

KELWAY BLACK

Originated by ——————. *Introduced by* Kelway, 1912.

Donated by Kelway, 1912, 1913.

Description in brief — A deep maroon variety.

Description in detail — Color of standard purple-brown 166 (3–4), veined with plum-violet; wings plum-violet 172 (2–3). Flower large, hooded form; standard large, reflexed, with notched top and broad base; wings long and broad. Substance good. Flowers two to three, on medium stems. Very fragrant. Bloom profuse. Plant of medium height and slender growth. Leaflets narrow, pointed; tendrils green.

Comparison — Similar to Black Knight.

MONARCH

Originated by Eckford. *Introduced by* Eckford, 1891.

Donated by Morse, for evolution studies.

Description in brief — A deep maroon-violet.

Description in detail — Color of standard plum-violet 172 (4); wings bright violet-purple 190 (4), back rich pansy-violet 191 (1–2). Flower of medium size, hooded form; standard of medium size, slightly hooded; wings long and narrow. Moderately productive. Plant of medium height.

Comparison — Indigo King is smaller and less desirable. Duke of Sutherland is larger and has more blue in the wings.

PURPLE KING

Originated by Eckford. *Introduced by* Eckford, 1908.

Description in brief — A very large, purple flower.

PURPLE PRINCE

Originated by Eckford. *Introduced by* Eckford, 1889.

Donated by Morse, for evolution studies.

Description in detail — Color of standard and wings 190 (2–4); standard deeper than wings. Flower of medium size, hooded; standard of medium size, hooded.

Fancy

DORA BREADMORE

Originated by Breadmore. *Introduced by* Breadmore, 1906.

Donated by Boddington, 1910.

Description in brief — A slightly hooded primrose self, shaded buff.

Description in detail — Standard and wings fleshy white 9 (3–4). Flower of medium size, hooded form; standard of medium size, slightly hooded, with round top; wings short and broad, partly open. Flowers three, irregularly placed on strong stems of moderate length. Very fragrant. Bloom moderate. Plant of tall, moderately strong growth.

Comparison — Somewhat similar to Lady M. Ormsby Gore, but lighter.

LADY M. ORMSBY GORE

Originated by Eckford. *Introduced by* Eckford, 1901.

Donated by Boddington, 1910.

Description in brief — A very light primrose.

Description in detail — Color of standard and wings amber-white 12 (1). Flower of medium size, hooded form; standard of medium size, extremely hooded, with round top; wings long and broad, spreading. Flowers two to three, usually three, irregularly placed on long, strong stems. Very fragrant. Bloom profuse. Plant of tall, strong growth. Leaflets pointed; tendrils colored.

Comparison — Coquette is said to have had more pink color. Queen Victoria has less substance, more primrose color, and a pinkish tint in the standard.

Remarks — On this soil and with the hot sunshine, no pink was noticed.

MARCHIONESS OF CHOLMONDELEY

Originated by Eckford. *Introduced by* Eckford, 1904.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — Cream, overlaid with pink.

Description in detail — Color of standard pale rosy pink 129 (1); wings very lightly tinted pale rosy pink 129 (1); both on a cream ground. Flower of medium size, hooded form; standard of medium size, hooded, with round top; wings short and broad, spreading. Flowers two, equidistant on strong stems of medium length. Bloom profuse. Plant of tall, strong growth. No color in axils.

Comparison — This variety has lighter wings than Venus, which it resembles in the standard.

MRS. FITZGERALD

Originated by Eckford. *Introduced by* Eckford, 1900.

Synonyms — This is reported as being the same as the variety Stella Morse (Burpee, 1898).

MRS. H. KENDALL BARNES

Originated by ————. *Introduced by* Dobbie, 1905.

Description in brief — Standard cream, tinted a very light pink; wings light primrose.

Comparison — Differs from Lady M. Ormsby Gore in having pink in the standard.

STELLA MORSE

Originated by Morse. *Introduced by* Burpee, 1898.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — Cream, tinted pink.

Description in detail — Color of standard and wings amber-white 12 (1), tinted lilacy white 7 (4); deeper color at edges; general effect is creamy yellow; buds very yellow. Flower of medium size, hooded form; standard of medium size, slightly hooded, with round top; wings short and broad, spreading. Flowers three, irregularly placed on long, strong stems. Moderately fragrant. Bloom profuse. Plant of tall, strong growth. Leaflets narrow, pointed; tendrils green.

Comparison — Modesty and Duchess of Sutherland are the same, but on a white ground.

Synonyms — Mrs. Fitzgerald is a synonym.

SUE EARL

Originated by Morse. *Introduced by* Burpee, 1903.

Donated by Burpee, 1910.

Description in brief — Primrose, with a shading of mauve-rose; wings primrose.

Description in detail — Color of standard amber-white 12 (1–2); wings amber-white 12 (2–3); the standards of the lower blossoms take on a tinge of mauve-rose. Flower of medium size, hooded form; standard of medium size, hooded; wings long and broad.

Remarks — Sent out for trial in 1902. Said to have been a cross between Lottie Eckford and Mrs. Eckford.

Lavender

CELESTIAL

Originated by C. Lorenz. *Introduced by* Lorenz, 1896.

Synonyms — (See New Countess.)

COUNTESS OF RADNOR

Originated by Eckford. *Introduced by* Eckford, 1890.

Donated by Burpee, 1910, 1911.

Description in brief — A lavender variety.

Description in detail — Color of standard heliotrope 188 (1–2); wings heliotrope 188 (1). Flower of medium size; standard of medium size; wings medium long and narrow. Flowers two to three. Very fragrant. Bloom profuse. Suitable for home decoration.

Comparison — Soon after it was sent out, Countess of Radnor had too much red in the standard. New Countess and Celestial were improvements in color.

FLORIST LAVENDER

Originated by ————. *Introduced by* Bath, 1909.

Comparison — Said to be a sport of Navy Blue.

J. T. CRIER

Originated by Breadmore. *Introduced by* Breadmore, 1907.

Description in brief — A lavender self.

LADY COOPER

Originated by Breadmore. *Introduced by* Breadmore, 1906.
Description in brief — A slightly hooded, clear lavender self.

LADY GRIZEL HAMILTON

Originated by Eckford. *Introduced by* Eckford, 1899.
Donated by Boddington, 1910; Burpee, 1911.
Description in brief — A violet and lilac-mauve variety.
Description in detail — Color of standard violet-mauve 195 (1–2); wings lilac-mauve 196 (1–2); the back in each being a shade deeper. Flower large; standard large, hooded; wings long and broad. Flowers two to three, on long, moderately strong stems. Very fragrant. Bloom profuse. Suitable for home decoration or for market. Plant of moderately vigorous growth.
Comparison — Is deeper in color than Countess of Radnor, but fades to the same shade.
Remarks — The best of its color in the old type.

LADY NINA BALFOUR

Originated by Eckford. *Introduced by* Eckford, 1897.
Description in brief — Standard mauve, wings lavender.

MADELINE COLE

Originated by Stark. *Introduced by* Stark, 1910.
Description in brief — A pale lavender self.

MINNIE KEEPERS

Originated by ————. *Introduced by* May, 1895.
Description in brief — " Flower large. Standard hooded. Color, standard pinkish lilac, wings lilac. Bloom medium."— Bulletin 111 of this station. Described by May as a " delicate lavender."

MRS. GEORGE HIGGINSON, JR.

Originated by Morse. *Introduced by* Vaughan, 1904.
Donated by Boddington, Vaughan, 1910; Burpee, 1911.
Description in brief — A very light lavender variety.
Description in detail — Color of standard and wings Parma violet 200 (1–2). Flower of medium size; standard of medium size, slightly hooded; wings medium long and narrow, hooded, concealing the keel. Flowers two to three, on long, strong stems. Very fragrant. Bloom profuse. Suitable for home decoration.
Synonyms — True Lavender is the same variety.

MRS. ISAAC HOUSE

Originated by ————. *Introduced by* House, 1910.
Description in brief — " Silvery lavender."— Sweet Pea Annual.

NEW COUNTESS

Originated by ————. *Introduced by* Burpee, 1897.
Description in brief — A selected strain of Countess of Radnor with no reddish mauve in the standard.

Synonyms — Same as Celestial.
Remarks — "A selection from a single plant."— Sweet Peas Up to Date.

THE FAIRY

Originated by ——————. *Introduced by* Johnson, 1907.
Description in brief — Opens white, changing to lavender.

TRUE LAVENDER

Originated by ——————. *Introduced by* Bath, 1909.
Description in brief — A light lavender variety.
Synonyms — This is said to be another name for Mrs. George Higginson, jr.

Magenta-Rose

EARL CROMER

Originated by Eckford. *Introduced by* Eckford, 1907.
Donated by Morse, 1910; Burpee, 1911.
Description in brief — A deep reddish mauve.
Description in detail — Color of standard and wings vinous-mauve 184 (1). Flower large, hooded form; standard large, slightly hooded, with round top; wings of medium size, concealing the keel. Flowers two to three, on medium stems. Very fragrant. Bloom profuse, continuous. Burns slightly. Plant of medium height and strong growth. Leaflets narrow, pointed; some plants show color in the developing tendrils; pedicels red; calyx shows some color.
Remarks — A distinct color.

FASHION

Originated by Morse. *Introduced by* Burpee, 1899.
Description in brief — A medium-sized, hooded, rose-magenta self.

GEORGE GORDON

Originated by Eckford. *Introduced by* Eckford, 1907.
Description in brief — A deep reddish mauve.

LORD KENYON

Originated by Eckford. *Introduced by* Eckford, 1900.
Description in brief — A medium-sized, hooded, magenta-rose variety.

LORD ROSEBERRY

Originated by Eckford. *Introduced by* Eckford, 1902.
Donated by Boddington, 1910; Burpee, 1911.
Description in brief — A rosy magenta variety.
Description in detail — Color of standard violet-rose 154 (4); wings pure mauve 181 (3–4). Flower medium to large, hooded form; standard medium to large, with round top; wings of medium size, long and broad, concealing the keel. Flowers two to three, on long stems. Bloom profuse, continuous. A garden variety. Plant of medium height, but stout and healthy.
Comparison — Similar to Lord Kenyon, but larger. Ovid has less violet color, and is therefore lighter. American Queen is the open-form variety of this color.
Remarks — One of the best of its color.

Marbled

DAWN

Originated by Walker. *Introduced by* Walker, 1898.

Description in brief — "An improved Gray Friar. A beautiful pea with many double flowers" — American Florist, 1900.

Comparison — Said to be a selection from Princess of Wales, the color being a marbled Princess of Wales on white ground.

EXQUISITE

Originated by Bath. *Introduced by* Bath, 1910.

Description in brief — Veined with blue on a white ground.

GLADYS FRENCH

Originated by Unwin. *Introduced by* Unwin, 1909.

Donated by Unwin, 1910; Burpee.

Description in brief — A pale Helen Pierce.

Description in detail — Standard veined, mottled, and marbled with light bluish violet 202 (1) on a purplish-tinted white 6 (2) ground; wings purplish-tinted white 6 (2), veined on back 202 (1). Flower of medium size, open form; standard of medium size, flat, with notched top; wings long and broad, concealing the keel. Flowers two to three on stems. Very fragrant. Bloom profuse, continuous. Sunproof. Plant of medium height, strong, healthy. Leaflets narrow, pointed; tendrils green.

Comparison — Differs from Helen Pierce chiefly in the amount of color in the flower.

GRAY FRIAR

Originated by Morse. *Introduced by* Burpee, 1896.

Description in brief —A large, hooded flower, marbled with heliotrope on a white ground.

Remarks — The watered grayish effect of the color suggested the name.

PERDITA

Originated by ————. *Introduced by* Bath.

Description in brief — Marbled with pink on a white ground.

PINK FRIAR

Originated by Morse. *Introduced by* Burpee, 1899.

Description in brief — A large, hooded flower, lightly marbled with rose-crimson on a white ground.

SPECKLED BEAUTY

Originated by Morse. *Introduced by* Vaughan, 1904.

Description in brief — A large, hooded flower, lightly marbled with light rose-crimson on a primrose ground.

Comparison — Is Pink Friar on a primrose ground.

Synonyms — Domino (Henderson, 1905) is the same variety.

Remarks — The history of Speckled Beauty and Pink Friar indicates that they cannot be fixed.

Mauve

ADMIRATION

Originated by ————. *Introduced by* Burpee, 1900.

Donated by Burpee, 1910, 1911.

Description in brief — A rosy lavender.

Description in detail — Color of standard heliotrope 188 (1–3); wings 188 (2). Flower of medium size or larger, hooded form; standard of medium size, hooded, sometimes showing trace of an apical notch; wings long and narrow, concealing the keel. Flowers three, irregularly placed on very long, strong stems. Very fragrant. Bloom profuse, continuous. Plant of medium height and strong growth. Leaflets narrow, pointed; axillary color with the leaflets and sometimes with the leaves; tendrils green.

Remarks — " Coquette × Emily Eckford."— Morse's Field Notes on Sweet Peas.

ARGOSY

Originated by ————. *Introduced by* House.

Description in brief — Lavender pink.

DOROTHY TENNANT

Originated by Eckford. *Introduced by* Eckford, 1892.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — Large, hooded; flower rosy mauve, changing to heliotrope.

Description in detail — Color of standard bishop's violet 189 (2), changing to heliotrope 188 (1); wings heliotrope 188 (1–2). Flower medium to large, hooded form; standard medium to large, hooded, with round top; wings long and narrow, concealing the keel. Flowers two to three, on long, medium stems. Very fragrant. Bloom profuse, continuous. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Comparison — Newly open flowers of Dorothy Tennant resemble those of Emily Eckford, but the latter shade off toward blue.

EMILY ECKFORD

Originated by Eckford. *Introduced by* Eckford, 1893.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — A purple-mauve, changing to light blue.

Description in detail — Color of standard and wings purplish mauve 186 (1–2); wings become more blue as the flower ages. Flower of medium size, hooded form; standard of medium size, hooded slightly, with notched top; wings long and broad, concealing the keel. Flowers two to three, on medium stems. Very fragrant. Bloom profuse, continuous. Sunproof. Plant of tall, strong growth. Leaflets pointed; tendrils green.

Comparison — Dorothy Tennant resembles the recently opened blossoms.

Remarks — A cross between Mrs. Sankey and Splendour. Offered in America by Breck in 1893.

FASCINATION

Originated by Eckford. *Introduced by* Eckford, 1900.

Description in brief — " Standard magenta mauve; wings deep mauve."— Eckford's catalogue.

MRS. BIEBERSTEDT

Originated by ———————. *Introduced by* Bell & Bieberstedt, 1908.

Donated by Boddington, 1910, Burpee, 1911.

Description in brief — A deep lavender self.

Description in detail — Color of standard and wings purplish mauve 186 (1–2), changing to heliotrope 188 (1–3). Flower large, hooded form; standard large, slightly hooded, with round top, wings long and broad, partly open. Flowers two to three, usually three, on long stems. Very fragrant. Bloom profuse. Sunproof. Plant of strong, vigorous growth. Leaflets broad; tendrils green.

Remarks — Distinct, and a very desirable variety for the garden.

MRS. TOM FOGG

Originated by Jones. *Introduced by* Jones, 1908.

Description in brief — " Mauve tinted pink."— Sweet Pea Annual.

MRS. WALTER WRIGHT

Originated by Eckford. *Introduced by* Eckford, 1903.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — Standard heliotrope, wings violet.

Description in detail — Color of standard shades from pale light lilac 187 (2) to heliotrope 188 (2); wings bishop's violet 189 (1). Flower large, hooded form; standard large, extremely hooded, with round top; wings long and very broad, partly open. Flowers two to three, on long, strong stems. Moderately fragrant. Bloom profuse, continuous. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Comparison — Color intermediate between Dorothy Tennant and Emily Eckford. Mrs. Walter Wright is larger than either.

ROMOLO PIAZZANI

Originated by Eckford. *Introduced by* Eckford.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — A violet-blue, the wings changing to light lilac.

Description in detail — Color of standard bluish lilac 183 (1); wings pale light lilac 187 (1). Flower of medium size, hooded form; standard of medium size, hooded, with round top; wings long and broad, concealing the keel. Flowers two to three, equidistant on medium stems. Moderately fragrant. Bloom profuse, continuous. Sunproof. Plant of medium height and strong growth. Leaflets pointed; tendrils green.

Comparison — Less blue than Emily Eckford.

Orange Shades

BOLTON'S PINK

Originated by Bolton. *Introduced by* Bolton, 1905.

Donated by Boddington.

Description in brief — An orange-pink variety.

Description in detail — Color bronzy old rose 148 (4); wings dark old rose 149 (1). Flower large, hooded form; standard large, hooded, without apical notch; wings long and broad, partly open. Flowers usually three, on long, strong stems. Moderately fragrant. Bloom profuse. Burns badly. Plant of tall, strong growth.

Comparison — Is distinct from Miss Wilmott.

BUTTONHOLE

Originated by ———————. *Introduced by* Miss Hemus, 1908.
Description in brief — A salmon-pink variety.

CHANCELLOR

Originated by Eckford. *Introduced by* Eckford, 1898.
Description in brief — Bright orange-pink.
Comparison — Lady Penzance is said to be practically the same, but is perhaps a little lighter.

LADY MARY CURRIE

Originated by Eckford. *Introduced by* Eckford, 1898.
Donated by Burpee, 1911.
Description in brief — Crimson-tinted orange.

MISS WILMOTT

Originated by ———————. *Introduced by* Eckford, 1901.
Donated by Boddington, 1910; Burpee, 1911.
Description in brief — Orange-pink, shaded with rose.
Description in detail — Color of standard violet-old rose 145 (2), edge purple-rose 150 (4); wings dark old rose 149 (2) in front and purple-rose 150 (2) on the back. Flower large, hooded form; standard large, hooded, without apical notch; wings long and broad, partly open. Flowers three, on long, strong stems. Very fragrant. Bloom profuse. Burns badly. Plant of very tall, strong growth.
Comparison — Is less resistant to hot sunshine than Miss Wilmott Improved.

MISS WILMOTT IMPROVED

Originated by ———————. *Introduced by* Watkins & Simpson, 1910.
Donated by Watkins & Simpson.
Description in brief — " Orange pink shaded rose."— Sweet Pea Annual.
Comparison — This proved to be a good strain of Miss Wilmott.

MRS. J. MILLER

Originated by Jones. *Introduced by* Jones, 1908.
Description in brief — Salmon-pink self.

ORIENTAL

Originated by Morse. *Introduced by* Burpee, 1898.
Description in brief — Bright orange-pink, veined with a deeper shade.

Picotee Edged (Lavender and Blue group)

BUTTERFLY

Originated by ———————. *Introduced by* Sutton, 1878.
Donated by Morse, for evolution studies.
Description in brief — White, tinted purple and edged with blue.
Description in detail — Color of standard and wings edged lobelia blue 205 (1–2) on a purplish-tinted ground 6 (3–4). Flower small to medium size, hooded form;

standard small to medium size, hooded, with notched sides; wings short and broad. Flowers two to three on stems. Very fragrant. Bloom profuse. Plant of tall, strong, healthy growth. Leaflets narrow, pointed; tendrils green.

Comparison — Butterfly, Maid of Honor, and Lottie Eckford vary in the amount of coloring distributed in the flower.

Remarks — One of the most important varieties ever grown.

DOLLY VARDEN

Originated by Morse. *Introduced by* Burpee, 1898.

Donated by Morse, for evolution studies.

Description in brief — Standard light purple, with lighter edges; wings light purple-blue.

Description in detail — Color of standard bishop's violet 189 (3–4); wings heliotrope 188 (1–2). Flower of medium size, hooded form; standard of medium size, hooded when side notches are present, flat, with narrow base; wings long and broad. Flowers two to three, equidistant on stems. Very fragrant. Bloom profuse. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Comparison — Standard not the same color as Splendid Lilac. Described by Morse as practically a hooded form of Splendid Lilac.

GOLDEN GATE

Originated by Morse. *Introduced by* Burpee. 1897.

Description in brief — Standard soft pinkish mauve; wings light mauve. Flowers have peculiarly shaped wings, which stand up against the standard.

IVY MILLER

Originated by Miller. *Introduced by* Miller, 1908.

Donated by Burpee.

Description in brief — A light lilac, edged with blue and violet.

Description in detail — Color of standard and wings pale light lilac 187 (1); standard picotee-edged with aniline blue 202 (3); wings picotee-edged with violet-mauve 195 (1). Flower medium large, hooded form; standard of medium size, hooded, with round top; wings long and broad, concealing the keel. Flowers two to three, equidistant on long, strong stems. Very fragrant. Bloom profuse, continuous. Sunproof. Plant of medium height and strong growth, healthy. Leaflets narrow, pointed; tendrils green.

Comparison — Similar to Lottie Eckford in form and size. Has more color suffused in the flower. Superseded by Phenomenal.

LOTTIE ECKFORD

Originated by Eckford. *Introduced by* Eckford, 1890.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — A lilac-white variety, picotee-edged with blue.

Description in detail — Color of standard and wings lilacy white 7 (1–4), edged with ageratum blue 201 (3). Many double flowers. Flower medium to large, hooded form; standard medium to large, hooded, with round top; wings long and broad, concealing the keel. Flowers two to three, on medium stems. Moderately fragrant. Bloom profuse, continuous. Sunproof. Plant of medium height and fairly strong growth. Leaflets narrow, pointed, dark green; tendrils green.

Comparison — Butterfly is somewhat similar, but has less color when the flower opens and is smaller in size.

MAID OF HONOR

Originated by Morse. *Introduced by* Burpee, 1897.

Donated by Burpee, 1910, 1911.

Description in brief — White, edged and shaded with light blue.

Description in detail — Color of standard and wings lilacy white 7 (2–3), edged with ageratum blue 201 (2–3). Flower of medium size, hooded form; standard of medium size, hooded, with round top and many side notches; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Very fragrant. Bloom profuse, continuous. Sunproof.

Comparison — Lottie Eckford is superior.

Synonyms — Butterfly Improved (Henderson Catalogue, 1898) is a synonym.

PHENOMENAL

Originated by Morse. *Introduced by* Henderson, 1905.

Donated by Morse, Vick, 1910; Burpee, 1911.

Description in brief — White, shaded and edged with mauve and heliotrope.

Description in detail — Color of standard lilacy white 7 (3–4), picotee-edged with violet-mauve 195 (1) changing to heliotrope 188 (1); wings edged with Parma violet 200 (1). Flower large, hooded form; standard large, hooded, sometimes inclined to be wavy; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Fragrant. Bloom profuse, continuous. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed, dark green.

Remarks — The best of the picotee-edged blue varieties of this form. One of the best doubles.

Picotee Edged (Pink group)

DAINTY

Originated by Morse. *Introduced by* Burpee, 1903.

Donated by Boddington, 1910; Burpee, 1911.

Description in detail — Color of standard purplish-tinted white 6 (1), edged with violet-rose 154 (1), deeper color on back; wings purplish-tinted white, edge same; general effect is pure white with pink edges; primrose-yellow in the bud. Flower of medium size, hooded form; standard of medium size, slightly hooded, shell-shaped, with round top; wings long and narrow. Flowers three, equidistant on long, strong stems. Very fragrant. Bloom profuse. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green; color appears in axils of leaves and leaflets.

Synonyms — Pink Butterfly is a synonym.

Remarks — Some seed was sent out for advance trial in 1902.

NYMPHAEA

Originated by Morse. *Introduced by* Morse, Vaughan, 1904.

Donated by Morse, Vaughan, 1910.

Description in detail — Color of standard amber-white 12 (2); wings 12 (1), changing to pale light lilac 187 (1) except the top flower, which remains white. Flower of medium size, hooded form; standard of medium size, slightly hooded, with slightly wavy edges and round top; wings long and broad, upright. Flowers three, equidistant on the stem. Moderately fragrant. Bloom profuse. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green; axillary color in leaves and leaflets.

Pink

FLORRIE CRUTCHER

Originated by ————. *Introduced by* Jones, 1908.

Description in brief — Rose-pink, veined with deeper pink.

LORD DERBY

Originated by ————. *Introduced by* May, 1894.

Description in detail — "Flowers small. Standard slightly concave, wedge-shaped. Color, standard pink, wings purple-pink. Bloom medium."— Bulletin 111 of this station.

Remarks — Color illustration appears on back cover of May's catalogue for 1895.

LOVELY

Originated by Eckford. *Introduced by* Eckford, 1896.

Donated by Boddington, 1910; Burpee, 1911.

Description in detail — Color of standard and wings mauve-rose 153 (1–3) on a white ground; color lighter at edges. Flower of medium size, hooded form; standard of medium size, hooded, with round top; wings short and broad, partly open. Flowers three, equidistant on long, strong stems. Very fragrant. Bloom profuse, continuous. Sunproof. Plant of tall, strong, healthy growth. Leaflets broad, pointed; tendrils green.

Comparison — The perfected type, of which Peach Blossom, Isa Eckford, and Crown Princess of Prussia are inferior examples.

MRS. E. HERBERT

Originated by Jones. *Introduced by* Jones, 1908.

Description in brief — Lilac-pink, veined deeper.

MRS. KNIGHTS-SMITH

Originated by Eckford. *Introduced by* Eckford, 1904.

Description in brief — A pink self, hooded, with wide-spreading wings.

PRIMA DONNA

Originated by Eckford. *Introduced by* Eckford, 1896.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — A pure pink self.

Description in detail — Color of standard and wings mauve-rose 153 (1). Flower above medium size, hooded form; standard above medium size, hooded, with round top; wings of medium size, short and broad, varying from partly open to spreading. Flowers two to three, usually three, on long, strong stems. Very fragrant. Bloom profuse. Plant tall, strong, vigorous, healthy. Leaflets broad; tendrils colored; color shown in axils of peduncles and leaflets.

Comparison —Blushing Beauty is similar, but is lighter in color. Royal Robe is slightly darker and is smaller.

Remarks — The leading pink variety of the old type.

QUEEN OF PINKS

Originated by ————. *Introduced by* Sutton, 1901.

Synonyms — Said to be another name for Prima Donna.

Prima Donna

Double sweet pea White Wonder

ROSE QUEEN

Originated by Stark. *Introduced by* Stark, 1905.
Description in brief — A rosy pink self.

ROYAL ROBE

Originated by Eckford. *Introduced by* Eckford, 1893.
Description in brief — A light pink self.

Striped and Flaked (Chocolate stripes)

SENATOR

Originated by Eckford. *Introduced by* Eckford, 1891.
Donated by Burpee, 1911.
Description in brief — A large, chocolate-striped variety.
Description in detail — Standard and wings striped with purple-brown 166 (1–2) on a purplish-tinted 6 (2) ground. Flower large, hooded form; standard large, hooded, with round top, wings long and broad. Fragrant.

Striped and Flaked (Mauve or blue)

CAPRICE

Originated by ——————. *Introduced by* Henderson, 1888.
Description in brief — "White watered and striped with mauve."— Henderson's catalogue.

DOUGLAS BREADMORE

Originated by Breadmore. *Introduced by* Breadmore, 1906.
Description in brief — Slightly hooded, flaked with bright purple.

JUANITA

Originated by Morse. *Introduced by* Burpee, 1896.
Donated by Morse, for evolution studies.
Description in brief — White, standard striped with mauve and wings striped with lavender.
Description in detail — Color of standard heliotrope 188 (1) on a lilacy white 7 (1–2) ground; wings suffused with heliotrope. Flower of medium size, hooded form; standard of medium size, hooded, with notched top; wings of medium size, long and broad, partly open. Flowers two to three, usually two, on long, strong stems. Fragrant. Bloom profuse, continuous. Plant of slender growth.
Comparison — Similar to Striped Celestial (Lorenz, 1897).
Remarks — The stock of this was mixed.

NITA

Originated by Walker. *Introduced by* Walker, 1898.
Description in brief — A pale mauve stripe on a white ground.
Comparison — Superseded by Juanita.

PRINCESS OF WALES

Originated by Eckford. *Introduced by* Eckford, 1886.
Description in brief — A hooded flower, striped with mauve and purple on white.
Comparison — Between Senator and Wawona in color.

STRIPED CELESTIAL

Originated by Lorenz. *Introduced by* Lorenz, 1897.

Donated by Morse, for evolution studies.

Description in detail — Color of standard heliotrope 188 (1) on a lilacy white 7 (1–2) ground; wings suffused with heliotrope. Flower of medium size, hooded form; standard of medium size, hooded, with notched top; wings of medium size, long and broad, partly open. Flowers two to three, usually two, on long, strong stems. Fragrant. Bloom profuse, continuous. Plant of slender growth.

Comparison — Similar to Juanita.

Remarks — The stock of this was pure.

STRIPED TENNANT

Originated by Walker. *Introduced by* Walker, 1898.

Description in brief — " A darker form of Nita."— Walker's catalogue.

UNIQUE

Originated by Stark. *Introduced by* Stark, 1906.

Donated by Rawson.

Description in brief — White, striped with light blue.

Description in detail — Color of standard Parma violet 200 (3) on a white ground; wings Parma violet 200 (1–2) on a white ground. Flower of medium size; standard of medium size, slightly hooded, with round top; wings long and broad, concealing the keel. Flowers two, on long, strong stems. Fragrant. Bloom profuse, continuous. Garden variety. Plant of tall, stout growth.

Comparison — May be known as Flora Norton striped white.

Remarks — A distinct variety.

WAWONA

Originated by Morse. *Introduced by* Burpee, 1898.

Donated by Morse, for evolution studies.

Description in brief — A lilac stripe on a white ground.

Description in detail — Standard striped with violet-rose 154 (4), wings striped with magenta 182 (1), both on a purplish-tinted white 6 (4) ground. Flower of medium size, hooded form; standard of medium size, hooded, with round top; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Bloom profuse, continuous. Plant of medium height and slender growth. Leaflets narrow, pointed; tendrils green.

Comparison — Juanita is a lighter color.

Striped and Flaked (Red and rose on primrose ground)

EASTERN QUEEN

Description in brief — " Slightly flaked on cream ground."— Sweet Pea Annual.

FLORENCE MOLYNEAUX

Originated by Dobbie. *Introduced by* Dobbie, 1905.

Description in brief — Lightly striped with rose on a primrose ground.

GOLDEN ROSE

Originated by Morse. *Introduced by* Burpee, 1902.

Donated by Burpee, 1910.

Description in detail — Color of standard amber-white 12 (3); wings amber-white 12 (1–2), faintly striped with pink, which in hot sunshine quickly disappears. Flower large, hooded form; standard large, slightly hooded, with round top; wings very large, long and broad. Flowers two to three, on medium stems. Moderately fragrant. Bloom profuse, continuous. A garden variety. Plant of tall, strong growth. Leaflets broad; tendrils green.

JESSIE CUTHBERTSON

Originated by Dobbie. *Introduced by* Dobbie, 1903.

Donated by Dobbie, 1910; Burpee, 1911.

Description in brief — Pink stripe on a primrose ground.

Description in detail — Color Rose Neyron red 119 (3) stripes on a yellowish white 13 (2) ground. Flower medium to large; standard medium to large, hooded, with round top; wings long and broad, concealing the keel Flowers two to three, on long, strong stems. Moderately fragrant. Bloom profuse, continuous.

Comparison — Sunset is darker.

LOTTIE HUTCHINS

Originated by Morse. *Introduced by* Burpee, 1898.

Description in brief — Slightly hooded, light pink stripe on a primrose ground.

SUNSET

Originated by Morse. *Introduced by* Vaughan, 1904.

Donated by Vaughan, 1910.

Description in detail — Color of standard purple-rose 150 (1–2) stripes on a purplish-tinted 6 (1–2) ground; wings 150 (2–3) on 6 (2–3) ground. Flower large, hooded form; standard large, slightly hooded, with round top; wings long and broad. Flowers two, on long, strong stems. Moderately fragrant. Bloom profuse, continuous. Plant of medium height and strong growth.

Comparison — Appeared to be a little more heavily striped, and at this station a little larger, than Jessie Cuthbertson.

Remarks — A badly mixed lot, from white to pink and lavender.

Striped and Flaked (Red and rose on white ground)

ANNIE STARK

Originated by Stark. *Introduced by* Stark, 1906.

Description in brief — A medium-sized, hooded flower. Lightly striped with light crimson on a white ground.

Comparison — A heavier stripe than Ramona, but otherwise similar.

AURORA

Originated by ———————. *Introduced by* Burpee, 1897.

Donated by Burpee, 1910, 1911.

Description in brief — White, striped with orange-rose.

Description in detail — Color Rose Neyron red 119 (1) on a sulfury white 14 (1) ground. Flower large; standard large, slightly hooded, with round top; wings long and

broad, concealing the keel. Flowers two to three, on long, strong stems. Moderately fragrant. Bloom profuse, continuous. A garden or exhibition variety. Plant of medium growth, stout, healthy.

Comparison — Mrs. Joseph Chamberlain does not have the orange tint. Coronet is the true open form of this variety, but becomes pale on the edges.

Remarks — This variety and Dorothy Eckford represent the perfection of the hooded form.

BRITANNIA

Originated by Dobbie. *Introduced by* Dobbie, 1904.

Description in brief — A slightly hooded flower, flaked with crimson on a white ground.

CAPRICE

Originated by ——————. *Introduced by* Johnson, 1906.

Description in brief — A large, slightly hooded flower, delicately striped with carmine on a white ground.

GAIETY

Originated by Eckford. *Introduced by* Eckford, 1893.

Donated by Morse, for evolution studies.

Description in brief — A red stripe on a rosy white ground.

Description in detail — Color of stripes of standard and wings solferino-red 157 (1–2) on a rosy white ground. Flower of medium size, hooded; standard of medium size, slightly hooded, showing both notched and round apices; wings long and broad. Flowers two to three, usually two, on long, strong stems. Fragrant. Bloom profuse, continuous. Plant of medium height and slender growth. Leaflets narrow, pointed; tendrils green.

LIGHT GAIETY

Originated by Walker. *Introduced by* Walker, 1898.

Description in brief — A light form of Gaiety.

Comparison — Superseded by Ramona.

MIKADO

Originated by Eckford. *Introduced by* Eckford, 1895.

Description in brief —A large, hooded flower, flaked with bright rose-crimson on a white ground.

MRS. JOSEPH CHAMBERLAIN

Originated by Eckford. *Introduced by* Eckford, 1895.

Description in brief — White, striped with rose.

Description in detail — Color of standard and wings rosy white 8 (1), striped with purple-rose 150 (1). Flower large; standard large, slightly hooded, with round top; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Moderately fragrant. Bloom profuse, continuous. Plant of medium height and stout, vigorous, healthy growth.

Comparison — Does not have the orange tint seen in Aurora.

Remarks — Said to be a cross between Captain of the Blues and Mrs. Sankey.

OREGONIA

Originated by Walker. *Introduced by* Walker, 1899.
Description in brief — A hooded flower, striped with brownish red on a white ground.

RAMONA

Originated by Morse. *Introduced by* Burpee, 1896.
Donated by Burpee, 1911.
Description in brief — A light pink stripe on a white ground.
Description in detail — Standard and wings striped with pale lilac-rose 130 (2) on a lilacy white 7 (1) ground.

White

ALBATROSS

Originated by Dobbie. *Introduced by* Dobbie, 1907.
Description in brief — A pure white, black-seeded variety.

BLANCHE BURPEE

Originated by Eckford. *Introduced by* Eckford, 1894.
Donated by Burpee, 1911.
Description in brief — A slightly hooded, pure white variety.
Description in detail — Flower medium to large, slightly hooded form; standard medium large, wings notched. Flowers two to three, on short, slender stems. Productive. Wet weather injures flowers. Plant of strong, vigorous growth. Seed white.

DOROTHY ECKFORD

Originated by Eckford. *Introduced by* Eckford, 1903.
Donated by Boddington, 1910; Burpee, 1911.
Description in brief — A large, pure white flower of ideal hooded form.
Description in detail — Color of standard and wings amber-white 12 (1), becoming pure white. Flower large; standard large, slightly hooded, with round top; wings large, long and broad. Substance good. Flowers three, on long, strong stems. Moderately fragrant. Bloom profuse, continuous. A leading market variety. Plant of tall, strong growth. Leaves dark green. Seed white.
Remarks — The ideal hooded type.

FINETTA BATHURST

Originated by Bathurst. *Introduced by* Mackereth, 1908.
Description in brief — A large, slightly hooded, white variety.

MRS. SANKEY

Originated by Eckford. *Introduced by* Eckford, 1889.
Description in brief — A pure white, black-seeded variety.

SADIE BURPEE (black-seeded)

Originated by Eckford. *Introduced by* Eckford, 1899.
Donated by Burpee, 1910.
Description in brief — A large, hooded, white variety.
Description in detail — Color of standard purplish-tinted white 6 (3); wings purplish-tinted white 6 (1). Flower large; standard large, much hooded, with round top;

wings medium broad, concealing the keel. Flowers three, on long, strong stems. Very fragrant. Plant of tall, erect, wiry growth. Leaves dark green; tendrils colored; color in axils of leaves and leaflets.

SADIE BURPEE (white-seeded)

Originated by Eckford. *Introduced by* Eckford, 1899.

Description in brief — A large, hooded, white variety.

Description in detail—Color of standard sage tint 4 (1); wings snow white 2 (1). Flower large; standard large, much hooded, with round top; wings of medium size, broad, concealing the keel. Very fragrant. Bloom profuse. Stems long and strong, with three flowers. Plant of tall growth. Leaves dark green; tendrils green; no color in axils.

Remarks — There is a form with black seed which shows a pinkish tint in the flowers.

THE BRIDE

Originated by Lynch. *Introduced by* Lynch, 1897.

Description in brief — A white-flowered variety of the type of Mrs. Eckford.

Remarks — This variety has white seed and was introduced as a white selection of Mrs. Eckford.

WHITE WONDER

Originated by Morse. *Introduced by* Burpee, 1904.

Donated by Boddington, Burpee, 1910; Burpee, 1911.

Description in brief — A large, pure white variety.

Description in detail — Color of standard and wings creamy white 10 (1); flower primrose when it opens, but changes to pure white. Flower large, double; standards often two or three, large and hooded; wings large, long and broad, partly open. Flowers two to four, on long, strong stems; fully one half are double under good culture. Fragrant. Bloom profuse. Plant of tall, strong growth.

Remarks — The best double white among the older type of sweet peas.

Yellow Shades

ALBION

Originated by Stark. *Introduced by* Stark, 1906.

Description in brief — An ivory-white variety.

CREAM OF BROCKHAMPTON

Originated by Foster. *Introduced by* Foster, 1902.

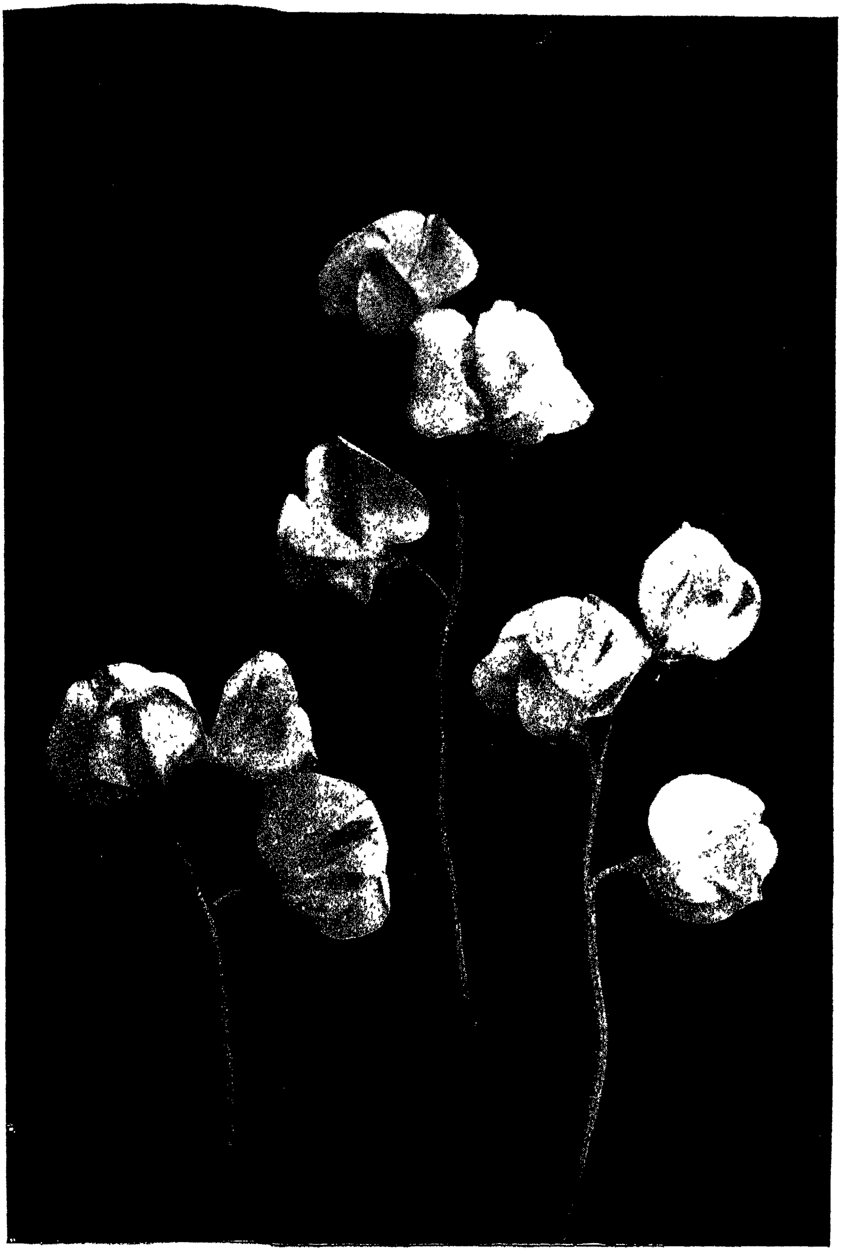
Description in brief — "A cream self."— Sweet Pea Annual.

FORTY-NINER

Originated by Sunset Seed and Plant Company. *Introduced by* Sunset Seed and Plant Company, 1898.

Description in brief — "A soft sulphur-yellow self."— Sweet Pea Review.

Comparison — Henderson placed this variety in the discard list in 1899, recommending Golden Gleam as superior.



James Grieve

Snapdragon sweet peas

GOLDEN GLEAM

Originated by ———. *Introduced by* Sunset Seed and Plant Company, 1897.

Donated by Morse, for evolution studies.

Description in brief — Described as a yellow form of Blanche Burpee.

Synonyms — Same as Mrs. Eckford.

JAMES GRIEVE

Originated by Eckford. *Introduced by* Eckford, 1908.

Donated by Dobbie, Rawson, 1910.

Description in brief — A large, yellow variety.

Description in detail — Color of standard sulfury white 14 (2–3); wings sulfury white 14 (3–4). Flower large, open form; standard large and erect, with occasional tendency to become slightly hooded and to show trace of the top notch; wings long and broad, spreading laterally, tending to parallel the standard. Flowers two to three, on extra long, strong stems. Very fragrant. Bloom profuse. Plant of tall, strong growth.

MRS. A. MALCOLM

Originated by Alexander Malcolm. *Introduced by* E. W. King, Mackereth, 1909.

Description in brief — A primrose self.

MRS. COLLIER

Originated by Dobbie. *Introduced by* Dobbie, 1907.

Donated by Boddington, Dobbie, 1910; Burpee, 1911.

Description in brief — A rich primrose variety.

Description in detail — Color of standard amber-white 12 (2); wings amber-white 12 (1). Flower large; standard large, slightly hooded, with round top; wings long and broad, spreading. Flowers two to three, on strong stems of medium length. Very fragrant. Bloom profuse. Substance good. Plant of strong, tall growth. Foliage dark green.

Comparison — A primrose Dorothy Eckford.

Synonyms — Dora Cowper (Breadmore, 1907) and Mrs. R. F. Felton (Bolton, 1907).

MRS. ECKFORD

Originated by Eckford. *Introduced by* Eckford, 1892.

Donated by Burpee, 1910, 1911.

Description in brief — A large, semi-hooded, primrose variety.

Description in detail — Color of standard yellowish white 13 (1–2); wings yellowish white 13 (2–3). Flower above medium size; standard medium, slightly hooded, with round top; wings medium, short and broad. Flowers two to three, on very long, strong stems. Moderately fragrant. Bloom profuse. Plant of tall, strong growth.

Synonyms — Golden Gleam appears to be the same variety.

QUEEN VICTORIA

Originated by Eckford. *Introduced by* Eckford, 1897.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — A light primrose, with a tinge of pink.

Description in detail — Color of standard and wings lilacy white 7 (1–2); buds with a pinkish tinge, but more color in buds than in those of Mrs. Eckford; the pink color

disappears as the flower opens. Flower above medium size; standard of medium size, hooded; wings long and broad. Flowers three, on long, strong stems. Very fragrant. Bloom profuse. Plant of tall, strong growth. Tendrils colored at first, becoming green. Seed black.

SAFRANO

Originated by Gilbert & Son. *Introduced by* Gilbert, 1911.

Description in brief — A primrose variety.

THE HONORABLE MRS. E. KENYON

Originated by Eckford. *Introduced by* Eckford, 1901.

Donated by Boddington, 1910; Burpee, 1911.

Description in brief — A large, semi-hooded, primrose variety.

Description in detail — Color of standard yellowish white 13 (3); wings yellowish white 13 (2). Flower large; standard large, slightly hooded, with round top; wings of medium size, broad. Flowers two to three, on long stems of moderate strength. Fragrant. Plant of strong, tall growth. Plant, leaves, and stems have a yellow tinge.

YELLOW HAMMER

Originated by Breadmore. *Introduced by* Breadmore, 1909.

Description in brief — A sulfur-yellow self.

EXTREME HOODED VARIETIES

Snapdragon

PINK SNAPDRAGON

Originated by Morse. *Introduced by* Burpee, 1903.

Donated by Morse, for evolution studies.

Description in detail— Color of standard and wings Rose Neyron red 119 (1) on a rosy white 8 (1) ground. Flower small, snapdragon form. Stems long.

PURPLE SNAPDRAGON

Originated by ———. *Introduced by* Burpee.

Donated by Morse, for evolution studies.

Description in detail — Color of standard shades from bishop's violet 189 (2–3) to bright violet 190 (2–4); wings lilacy white 7 (4) to rich pansy-violet 191 (2–3). Flower of medium size, snapdragon form. Stems long.

RED RIDING HOOD

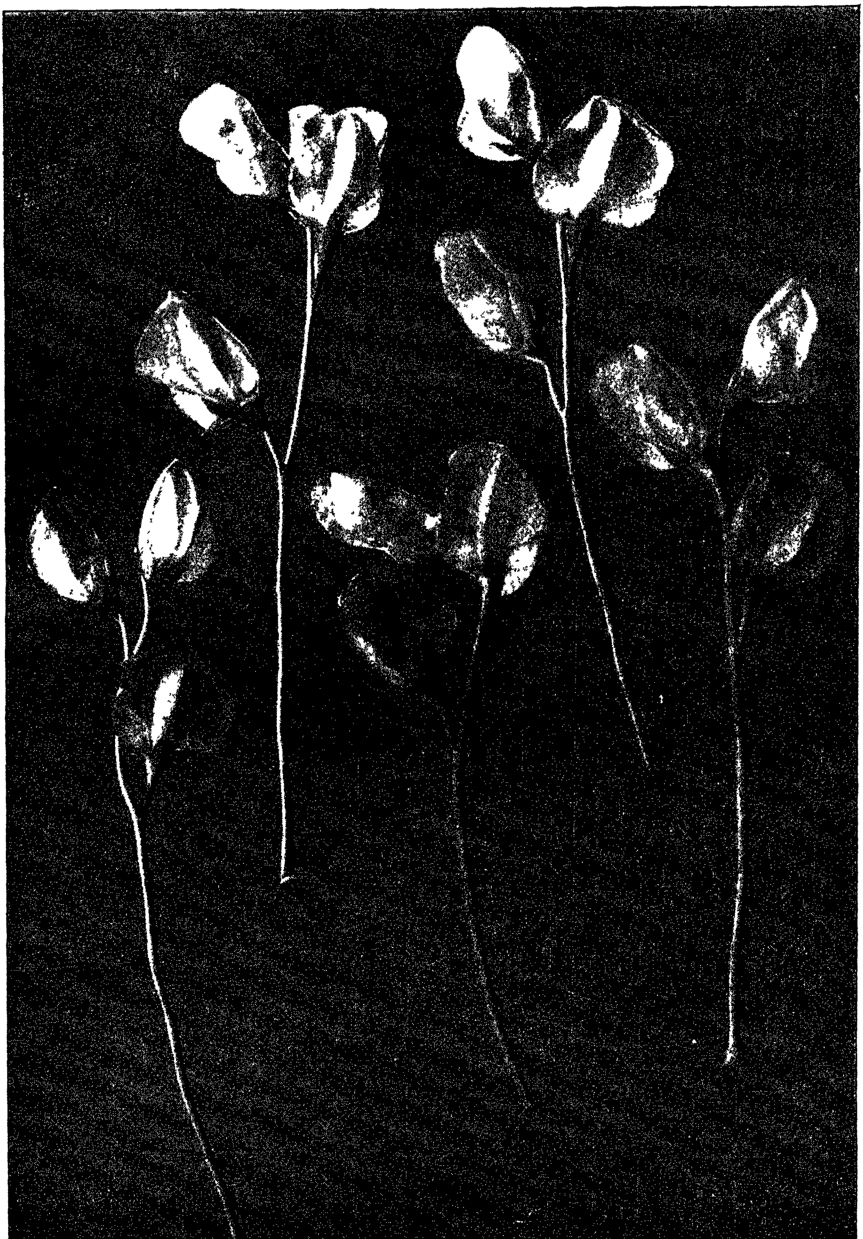
Originated by Sunset Seed and Plant Company. *Introduced by* Sunset Seed and Plant Company, 1897.

Donated by Morse, for evolution studies.

Description in brief — A crimson snapdragon variety.

Description in detail — Color of standard Rose Neyron red 119 (4) on a rosy white 8 (1) ground; wings Tyrian rose 155 (1). Flower large, snapdragon form; standard envelops the wings.

Remarks — The first of the snapdragon varieties.



Salvation Lassie

Apple Blossom Spencer

SALVATION LASSIE

Originated by ————. *Introduced by* Burpee, 1902.

Donated by Morse, for evolution studies.

Description in brief — " Light carmine, standards and wings hooded like a bonnet."— Burpee's catalogue.

Description in detail — Color of standard violet-rose 154 (1) on a rosy white ground; wings Tyrian rose 155 (1–2) on a rosy white ground. Flower large, snapdragon form; standard short, folded over wings like a bonnet; wings of usual type.

Comparison — Similar to Red Riding Hood, but with standard more fully developed.

Remarks — Valuable as a curiosity.

WHITE SNAPDRAGON

Originated by ————. *Introduced by* Burpee, 1902.

Donated by Morse, for evolution studies.

Description in brief — A white snapdragon variety.

WAVED VARIETIES

Bicolor

APPLE BLOSSOM SPENCER

Originated by ——————. *Introduced by* Burpee, 1908.

Donated by Burpee, Morse, 1910.

Description in brief — Large to very large, waved, rose bicolor; garden, market, or exhibition variety.

Description in detail — Color of standard lilac-rose 152 (4), wings violet-rose 154 (1–2), on a faint primrose ground. Standard large, much waved; wings very large, waved. Flowers two to four, on long, very stout stems. Fragrant. Bloom profuse and continuous. Sunproof. Plant of medium height and stout, healthy growth.

Comparison — A misnomer, for it is not like Apple Blossom. It should be called Jeannie Gordon Spencer, as the ground tint is primrose.

Remarks — Introducer's stock pure in 1910.

ARTHUR UNWIN

Originated by Unwin. *Introduced by* Unwin, 1910.

Donated by Unwin, 1910.

Description in brief — Large, waved, bicolor; carmine-purple and mauve-rose.

Description in detail — Color of standard carmine-purple 156 (1–2); wings mauve-rose 153 (1). Standard large, slightly waved; wings waved, long and broad, concealing the keel. Flowers two to four, on long, strong stems. Fragrant. Sunproof. Plant of medium height and stout, healthy growth.

Comparison — A deeper color than Colleen when viewed on the plants.

BLANCHE FERRY SPENCER

Donated by Rawson, Vick, 1910.

Description in brief — Supposed to be a waved variety of the color of Blanche Ferry.

Remarks — Mostly Apple Blossom Spencer. Contains a few Blanche Ferry, but they are not in Spencer form. Both stocks mixed with White Spencer and other varieties. Nothing has been received at this station since 1910 that could be called Blanche Ferry Spencer.

COLLEEN

Originated by William Deal. *Introduced by* Deal, 1910.

Donated by Deal, 1910, 1912.

Description in brief — Large, waved, bicolor.

Description in detail — Color of standard carmine-purple 156 (1–2), wings violet-rose 154 (1), on a primrose ground. Flower large, waved form; standard large, waved; wings large, exposing the keel. Flowers three to four, on strong stems. Plant of average growth, strong, healthy. Tendrils colored.

Remarks — An unfixed stock in 1910. Some of the sports approach George Herbert. In 1912 the stock was variable. Some flowers have white wings and carmine-purple standards and some are almost selfs; many show mottled flowers, especially as the flowers age.

MRS. ANDREW IRELAND

Originated by Dobbie. *Introduced by* Dobbie, 1909.

Donated by Dobbie, 1910.

Description in brief — A large, rose bicolor, waved variety.

Description in detail — Color of standard lilac-rose 152 (3–4); wings lilac-rose 152 (1). Standard large, waved; wings waved, long and broad, concealing the keel. Flow-

ers two to three, on medium stems. Fragrant. Bloom profuse, continuous. Sunproof. Plant of medium height, more slender than most waved varieties, and of healthy growth.

Remarks — Has many double flowers.

MRS CUTHBERTSON

Originated by Dobbie. *Introduced by* Dobbie, 1912.

Donated by Burpee, Dobbie, 1912, 1913.

Description in brief — A large, rose bicolor, waved variety.

Description in detail — Color of standard deep rose-pink 120 (2–3); wings violet rose 154 (1–4); has a tendency to produce mottled flowers. Flower large to very large, waved form; standard large, waved; wings long and broad. Flowers usually three, sometimes four, on very long, strong stems. Moderately fragrant. Plant of medium height, healthy, vigorous. Tendrils colored.

Remarks — An improved Apple Blossom. The best variety in this color section.

NEW IMPROVED LUCY HEMUS

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief —A large, waved, bicolor variety.

Description in detail — Color lilac-rose, standard 152 (2–3), wings 152 (1–2), on a primrose ground.

Synonyms — Synonymous with Apple Blossom Spencer, the probability of which the introducer admits.

Remarks — A very unfixed stock. The flowers became very mottled during the latter part of August.

TRIUMPH SPENCER

Originated by Bolton. *Introduced by* Bolton, 1909.

Donated by Unwin, 1910.

Description in brief — A rose bicolor.

Description in detail — Color of standard purple-rose 150 (3–4); wings violet-rose 154 (1).

Comparison — A smaller, inferior, shorter-stemmed Apple Blossom Spencer, also of weaker growth. Distinct from Mrs. Andrew Ireland.

Remarks — Not fixed. Described as a salmon-pink bicolor.

Blue

BLUE JACKET

Originated by Stark. *Introduced by* Stark, 1912.

Donated by Stark, 1912; Boddington, 1913.

Description in brief — A navy blue, waved variety.

Description in detail — Standard dark purple 191 (1); wings violet-purple 192 (2). Flower large, waved form; standard large, waved slightly; wings long and broad, spreading. Flowers three, on long, strong stems. Moderately fragrant. A moderately productive variety. Plants of tall, strong growth. Leaflets broad, pointed.

Remarks — In 1913 this variety broke up, giving one half dark blue stripes. Had it not done this it might be recommended as the best dark blue variety.

FLORA NORTON SPENCER

Originated by Morse. *Introduced by* Morse, 1909.

Donated by Morse, 1910; Burpee, 1911; Waldo Rohnert, 1912.

Description in brief — A medium-sized, slightly waved, blue variety for the garden.

Description in detail — Color of standard ageratum blue 201 (1); wings 201 (2). Standard medium large, waved slightly; wings of medium size, long and narrow, concealing the keel. Flowers two to three, on medium stems. Fragrant. Bloom profuse, continuous. Plant of medium height and strong, healthy growth.

Comparison — Not so pure a blue as Flora Norton. Does not equal Countess Spencer in size.

Remarks — Contained plant of Navy Blue in 1910.

LESLIE IMBER

Originated by Unwin. *Introduced by* Unwin, 1913.

Donated by Unwin.

Description in brief — Described as a medium blue, with deeper wings.

Description in detail — Color of standard purplish mauve 186 (4); wings light bluish violet 202 (1–2); both become more blue with age. Flower large, waved form; standard large, waved; wings short and broad, concealing the keel. Flowers two to three, on medium stems. Moderately fragrant. Bloom profuse. Sunproof. Plant of tall, slender growth. Leaflets dark green.

MARGARET MADISON

Originated by Morse. *Introduced by* Burpee, Morse, 1912.

Donated by Burpee, Morse, 1912; Burpee, 1913.

Description in brief — A large, waved, clear pale blue self.

Description in detail — Color of standard bluish violet 199 (1); wings lavender-blue 204 (1), sometimes flaked darker. Flower large, waved form; standard large, waved; wings long and broad, spreading. Flowers two to three, on medium stems. No fragrance. Moderately productive. Wet weather injures badly. Plant of medium height. Leaflets stout, broad, pointed; tendrils green.

Comparison — Slightly larger than Flora Norton Spencer.

MAY FARQUHAR

Originated by Unwin. *Introduced by* Unwin, 1911.

Donated by Unwin, 1913.

Description in brief — A deep blue, waved variety.

Description in detail — Color of standard plum-violet 172 (3–4), overlaid with deep purple; wings bright violet-purple 190 (2–3), with darker-colored back. Flower large, waved form; standard large, slightly waved; wings short and broad, concealing the keel. Flowers three to four, placed equidistant, close, on strong stems of medium length. No fragrance. Bloom profuse. Sunproof. Plant of tall, strong growth. Leaflets dark green, broad, round; tendrils green.

Remarks — Probably the best dark blue waved variety that is fixed.

SHAWONDASEE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — A medium-sized, garden variety.

Description in detail — Color of standard at base light bluish violet 202 (1), the upper part heliotrope 188 (2–3); wings 202 (1); the standard loses its pink color, becoming like the wings. Standard of medium size, slightly waved; wings of medium size, long and narrow. Flowers two to three, on fair stems. Fragrant. Bloom profuse. Plant of ordinary growth. Seed mottled.

Comparison — On trial grounds a deeper blue than Zephyr or Flora Norton Spencer.

Remarks — Stock pure.

SOUTHCOTE BLUE

Originated by Sutton. *Introduced by* Sutton, 1913.

Donated by Sutton, 1913.

Description in brief — A waved, deep blue variety.

Description in detail — Color of standard ageratum blue 201 (1–2); wings lavender-blue 204 (1–2). Flower of medium size, waved form; standard moderately large, slightly waved; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. No fragrance. Bloom medium. Sunproof. Plant of tall, strong growth. Leaflets broad, round, dark green.

Comparison — Resembles Flora Norton Spencer.

ZEPHYR

Originated by Biffen. *Introduced by* Miss Hemus, Unwin, 1909.

Donated by Miss Hemus, Unwin, 1910.

Description in brief — A medium-sized garden variety.

Description in detail — Color of standard ageratum blue 201 (1); wings 201 (2–3). Standard of medium size, slightly waved; wings of medium size, long and narrow. Flowers three, on fair stems. Fragrant. Bloom profuse. Plant of medium growth. Seed small, yellow-brown, wrinkled.

Comparison — Similar to Flora Norton Spencer.

Remarks — One stock fixed.

Blush

BLUSH QUEEN

Originated by Dobbie. *Introduced by* Dobbie, 1907.

Donated by Dobbie, 1910.

Description in brief — A blush-pink of Unwin form. An excellent garden variety.

Descripticn in detail — Color lilacy white 7 (1), fading to white. Flower medium to large; standard medium to large, Unwin type; wings small, short and narrow, partly open. Flowers three, on long stems. Fragrant. Bloom very profuse. Plant of tall and moderately strong growth. Color in axils of leaflets. Seed black.

Remarks — A fixed stock. One of the best in the blush-pink group.

BOBBY K.

Originated by Chandler. *Introduced by* Unwin, 1908.

Donated by Unwin, 1910.

Description in brief — A large, waved, blush-pink, fine garden variety.

Description in detail — Color of standard and wings lilacy white 7 (1). Standard large, Spencer-waved; wings of medium size, partly open. Flowers three, on long, strong stems. Fragrant. Bloom profuse, continuous. Plant of moderately strong and vigorous growth. Color in axils of leaves. Seed round, black.

Comparison — Color is lighter than Florence Morse Spencer.
Remarks — A pure stock.

FLORENCE MORSE SPENCER

Originated by Morse. *Introduced by* Morse, 1908.

Donated by Boddington, Morse.

Description in brief — A large, waved variety, for home, market, or exhibition use. Delicate blush, with pink margin.

Description in detail — Color of standard pale lilac-rose 130 (1); wings, front 130 (2), back 130 (3–4). Standard large, Spencer-waved; wings large, long and broad. Flowers three, on long, strong stems. Moderately fragrant. Bloom profuse.

Comparison — Similar to Mrs. Hardcastle Sykes, which has the prior name.

Remarks — One stock pure.

LADY ALTHORP

Originated by Silas Cole. *Introduced by* Cole, 1908.

Donated by Cole, 1910.

Description in brief — Introducer describes it as blush-white, changing to pure white.

Description in detail — Color of standard lilacy white 7 (3); wings mauve-rose 153 (1). Flower of medium size; standard of medium size, Unwin form; wings long and narrow, concealing the keel. Flowers two to three, on long stems of fair strength. Plant of tall, strong growth. Color in axils of leaves.

Comparison — Not equal to Mrs. Sankey Spencer, with which it is often grouped.

Remarks — A fixed stock. A deeper pink than any other variety of this group.

LADY EVELYN EYRE

Originated by Holmes. *Introduced by* Sydenham, 1912.

Donated by Sydenham, 1912.

Description in brief — A very large, waved, blush-pink variety.

Description in detail — Standard cream-white, edged and flushed with bright rose 128 (1); wings lighter than 128 (1). Flower very large, waved form; standard very large, waved, often double; wings large, long and broad, spreading. Substance good. Flowers three, on long, strong stems. Very fragrant. Bloom profuse. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed, dark green.

Comparison — Resembles Florence Morse Spencer in color, but is larger, has stronger stems, and gives a higher percentage of double or triple standards. The plant is stronger than Mrs. Hardcastle Sykes.

Remarks — The finest of the blush-pink varieties in 1912 and 1913.

LILA

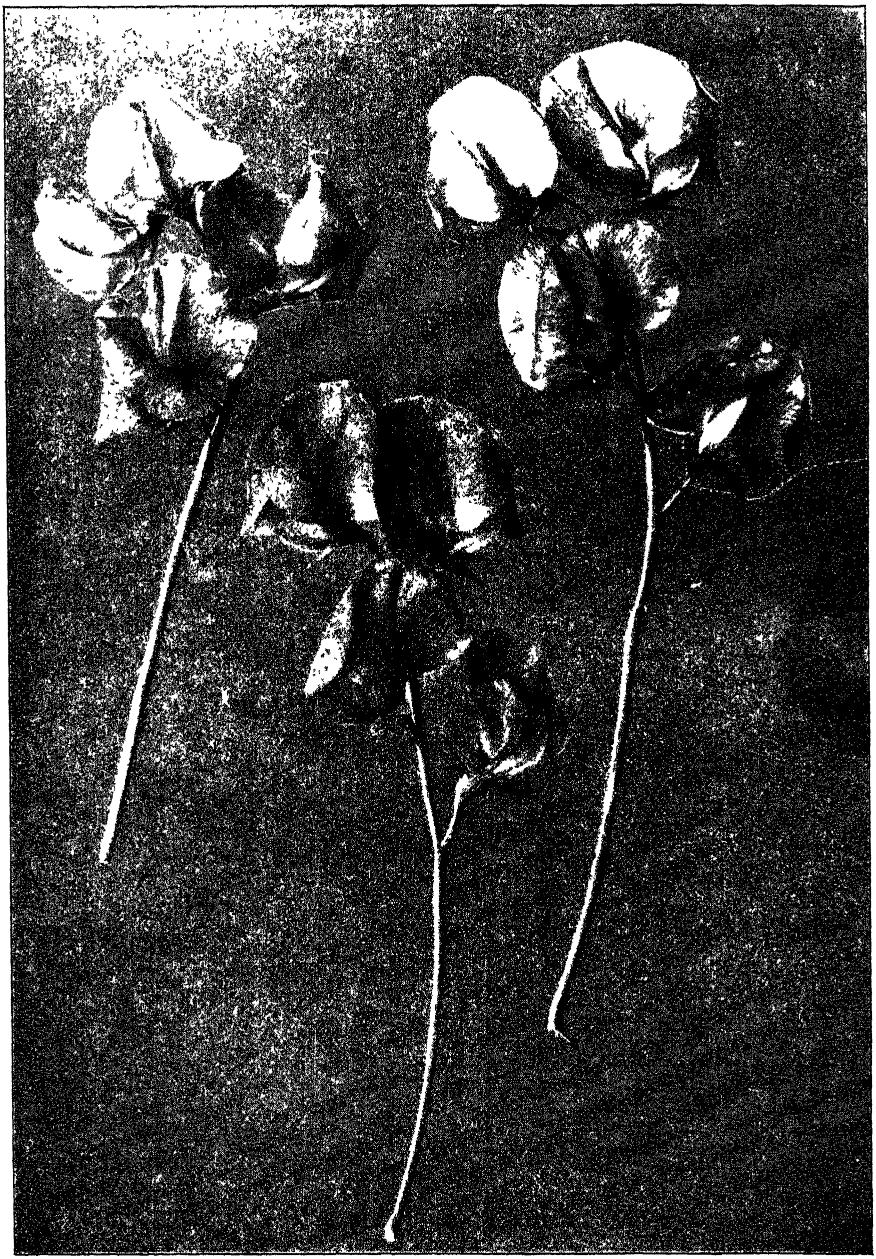
Originated by T. H. Dipnall. *Introduced by* Dipnall, 1913.

Donated by Dipnall, 1913.

Description in detail — Color of standard lilacy white 7 (1), veined and flushed with pale lilac; wings snow white 2 (1). Flower medium large, waved form; standard large, very slightly waved; wings short, broad, concealing the keel. Flowers three, on medium stems. Moderate fragrance. Bloom profuse. Sunproof. Plant of tall, slender growth. Leaflets broad, round, dark green.

Remarks — This appears to be distinct. Promising. Stock without color rogues.

Paradise Ivory *Florence Morse Spencer*



John Ingman

LORNA DOONE

Originated by Stark. *Introduced by* Stark, 1908.

Donated by Boddington, 1910.

Comparison — Said to be similar to Florence Morse Spencer and Bobby K.

Remarks — Only one seed grew, and the plant produced white flowers without any trace of color.

MRS. HARDCASTLE SYKES

Originated by Bolton. *Introduced by* Bolton, 1906.

Donated by Boddington, Miss Hemus, 1910.

Description in brief — A large, waved, blush-pink variety.

Comparison — Indistinguishable from Florence Morse Spencer, and has the prior name.

Remarks — One stock badly mixed.

PARADISE REGAINED

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1908.

Donated by Miss Hemus, 1910.

Description in brief — A large-flowered, blush, garden variety.

Description in detail — Color purplish-tinted white 6 (2–3). Standard large, slightly waved; wings long and broad, concealing the keel. Flowers three, on very long, strong stems. Fragrant. Bloom profuse. Plant of tall, strong growth. Tendrils colored; color in axils of leaves. Seed large, round, black.

Remarks — A pure stock.

PRINCESS CATHERINE

Originated by ——————. *Introduced by* Bath, 1909.

Donated by Vick, 1910.

Comparison — The blush-pink selection was not superior to Blush Queen.

Remarks — A very much mixed stock, containing plants with blush-pink, pink, primrose, and white flowers.

PRINCESS VICTORIA

Originated by Dobbie. *Introduced by* Dobbie, 1908.

Donated by Dobbie, 1910; Stark, Morse, Rohnert, 1912.

Description in brief — A large, waved, light pink variety, especially fine for exhibition.

Description in detail — Color of standard pale lilac-rose 130 (1–2); wings mauve-rose 153 (1–2). Flower large to very large; standard large to very large, very much waved; wings long and broad, concealing the keel. Flowers three to four, on long, strong stems. Fragrant. Plant of medium height and strong, healthy growth. Tendrils colored.

Comparison — Opening flowers a deeper pink than Florence Morse Spencer, but fading to the same color. In 1910 was superior to Florence Morse Spencer and Mrs. Hardcastle Sykes, and this has since been verified.

Remarks — A pure stock. Some seed-growers have assumed that this is Florence Morse Spencer, but such stocks can be distinguished from the true Princess Victoria.

Carmine

E. J. CASTLE

Originated by Unwin. *Introduced by* Unwin, and Watkins & Simpson, 1907.

Donated by Boddington, Rawson, Unwin, and Watkins & Simpson, 1910.

Description in brief — A large, waved, carmine-rose variety, for garden or market use.

Description in detail — Color of standard lilac-rose 152 (4); wings solferino-red 157 (1). Standard fairly large, Unwin form; wings long and broad, hooded. Flowers two to four, on long, strong stems. Fragrance slight or none. Bloom profuse.

Comparison — Similar to John Ingman in color, but not so wavy nor so large. More productive than John Ingman.

Remarks — Two stocks pure. Unwin's stock was superior to all others.

GEORGE HERBERT

Originated by Breadmore. *Introduced by* Breadmore, 1906.

Donated by Morse, Rawson, 1910.

Description in brief — A very large, waved, carmine-rose variety.

Comparison — Similar to John Ingman.

Remarks — Both stocks mixed, one with Othello, the other with White Spencer and Frank Dolby, one plant each.

JOHN INGMAN

Originated by Cole. *Introduced by* Sydenham, 1905.

Donated by Boddington, Cole, Dobbie, Morse, Unwin.

Description in brief — A very large, waved, carmine-rose, fine, exhibition variety.

Description in detail — Color of standard lilac-rose 152 (4); wings solferino-red 157 (1). Standard large to very large, very waved; wings large, long, waved, concealing the keel. Flowers two to four, on long, strong stems. Fragrance very slight or none. Bloom free, continuous. Growth strong, vigorous, healthy. Seed black.

Comparison — Superior to E. J. Castle in form.

Remarks — All stocks were pure as to color. The English stocks were superior in form. The leader of its color.

PARADISE CARMINE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1907.

Donated by Miss Hemus, 1910.

Description in brief — A large, waved, carmine-rose variety.

Comparison — Similar to John Ingman.

Remarks — A pure stock.

PHYLLIS UNWIN

Originated by Unwin. *Introduced by* Unwin, and Watkins & Simpson, 1906.

Donated by Rawson, and Watkins & Simpson, 1910.

Description in brief — A large, waved, carmine-rose variety.

Description in detail — Color of standard lilac-rose 152 (1); wings solferino-red 157 (1). Standard large, Unwin form; wings long and broad. Flowers three, on long, strong stems. Bloom free, continuous. Plant of strong, healthy growth. Seed round and black.

Comparison — Similar to E. J. Castle, but paler.

Remarks — English stock pure.

Cerise

CHRISSIE UNWIN

Originated by Unwin. *Introduced by* Unwin, 1908.

Donated by Unwin, 1910.

Description in brief — A medium-sized, cerise variety, suitable for home decoration.

Description in detail — Color of standard lilac-rose (cerise) 152 (4); wings deep cerise 123 (1–2). Standard of medium size, slightly waved; wings partly open, long and broad. Flowers two to three, on long, strong stems. Fragrance slight or lacking. Bloom profuse. Burns badly in sunshine. Growth below medium height, slender. Tendrils colored and clinging. Seed black.
Comparison — Superior to Coccinea Paradise.
Remarks — A pure stock. The variety lacks size.

COCCINEA PARADISE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910
Donated by Miss Hemus, 1910.
Description in brief — A cerise variety.
Description in detail — Color of standard Rose Neyron red 119 (3–4); wings 119 (1).
Synonyms — Appears to be Coccinea.
Remarks — Badly mixed with Red Paradise.

Cream, Buff, and Ivory

ALTHORP CREAM

Originated by Cole. *Introduced by* Cole, 1910.
Donated by Cole, 1910.
Description in brief — A large, waved, primrose variety.
Description in detail — Color of standard yellowish white 13 (2–3); wings 13 (1). Standard large, waved; wings long, very broad, concealing the keel. Substance poor. Flowers two to three, on strong stems of fair length. Moderately fragrant. Fairly productive. Plant of tall, strong, healthy growth. Seed white.
Comparison — Not equal to Primrose Spencer or Clara Curtis, which it is said to resemble.
Remarks — A mixed stock in 1910.

CLARA CURTIS

Originated by Bolton. *Introduced by* Bolton, Sharpe, 1908.
Donated by Dobbie, Unwin, 1910.
Description in brief — A large, waved, primrose variety.
Description in detail — Color of standard yellowish white 13 (2–3); wings 13 (1). Flower large to very large; standard large, Spencer-waved; wings large, waved. Flowers two to four, well arranged on long, strong stems. Moderately fragrant. Bloom profuse. Plant of tall, vigorous growth. Seed white.
Comparison — Similar to Primrose Spencer (Burpee, 1908), but all flowers truly waved.
Remarks — Both stocks pure.

DOBBIE'S CREAM

Originated by Dobbie. *Introduced by* Dobbie, 1912.
Donated by Dobbie, 1912, 1913.
Description in detail — Color of standard and wings creamy white 10 (1–2). Flower large, waved form; standard large, sometimes double or triple; opens rich yellow, becoming lighter. Flowers usually three, on long, strong stems. Productive. Sunproof. Plant of tall, stout growth. Leaflets broad, round, dark green.

DOUBLE PRIMROSE BEAUTY

Originated by Stark. *Introduced by* Stark, 1912.

Donated by Stark, 1912.

Description in brief — Similar to Primrose Beauty in every respect except that it produces a few more double flowers.

ELAINE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — A medium-sized, ivory variety of waved form, useful for garden purposes.

Description in detail — Color of standard fleshy white 9 (2–3); wings fleshy white 9 (3–4). Flower of medium size; standard of medium size, waved slightly; wings of medium size, short and broad, partly open, hooded. Flowers two to four, usually three, on long, strong stems. Fragrant. Bloom profuse. Plant of tall, strong growth. Some color in axils of leaves. Seed black.

Comparison — Resembles Paradise Ivory.

Remarks — Does not fulfill the originator's description.

GIANT CREAM WAVED

Originated by Deal. *Introduced by* Deal, 1911.

Donated by Deal, 1912.

Description in brief — A large, waved, cream variety.

Description in detail — Flower large, waved form; standard large, waved, sometimes double; wings long and broad. Flowers usually three, sometimes four, on long, strong stems. Productive.

Comparison — Not exceptional in size, being equal to Dobbie's Cream in this respect.

ISOBEL MALCOLM

Originated by Malcolm. *Introduced by* Dobbie, 1911.

Donated by Dobbie, 1912.

Description in brief — Large, waved, primrose self.

Description in detail — Color of standard and wings yellowish white 13 (1–3). Flower large, waved form; standard large, much waved; wings large, long and broad, spreading. Flowers three to four, usually three, on long, strong stems. Moderately fragrant. Plant of tall, strong, healthy growth. Leaflets broad, pointed, with axillary color; tendrils green.

Comparison — The general effect is paler than Clara Curtis. An excellent variety.

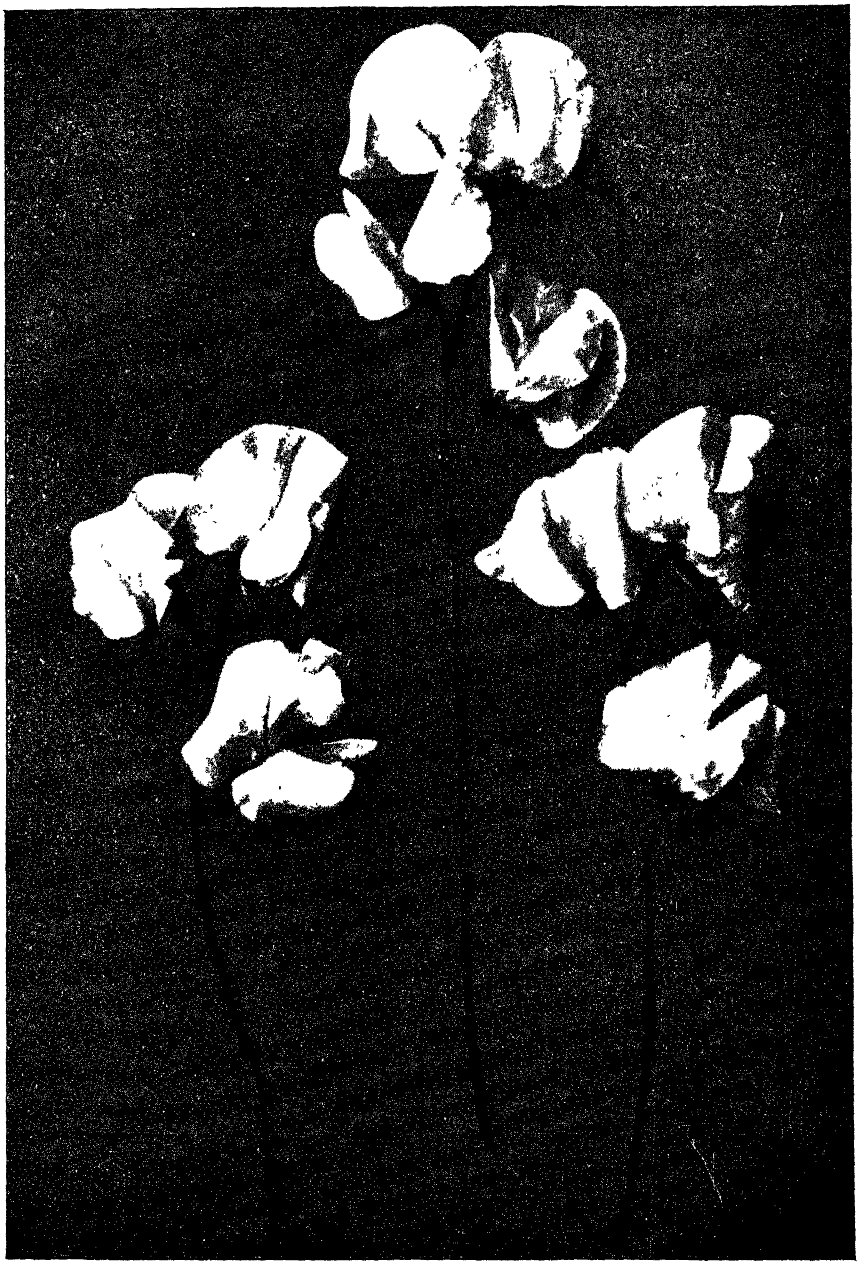
LADY KNOX

Originated by Dobbie. *Introduced by* Dobbie, 1912.

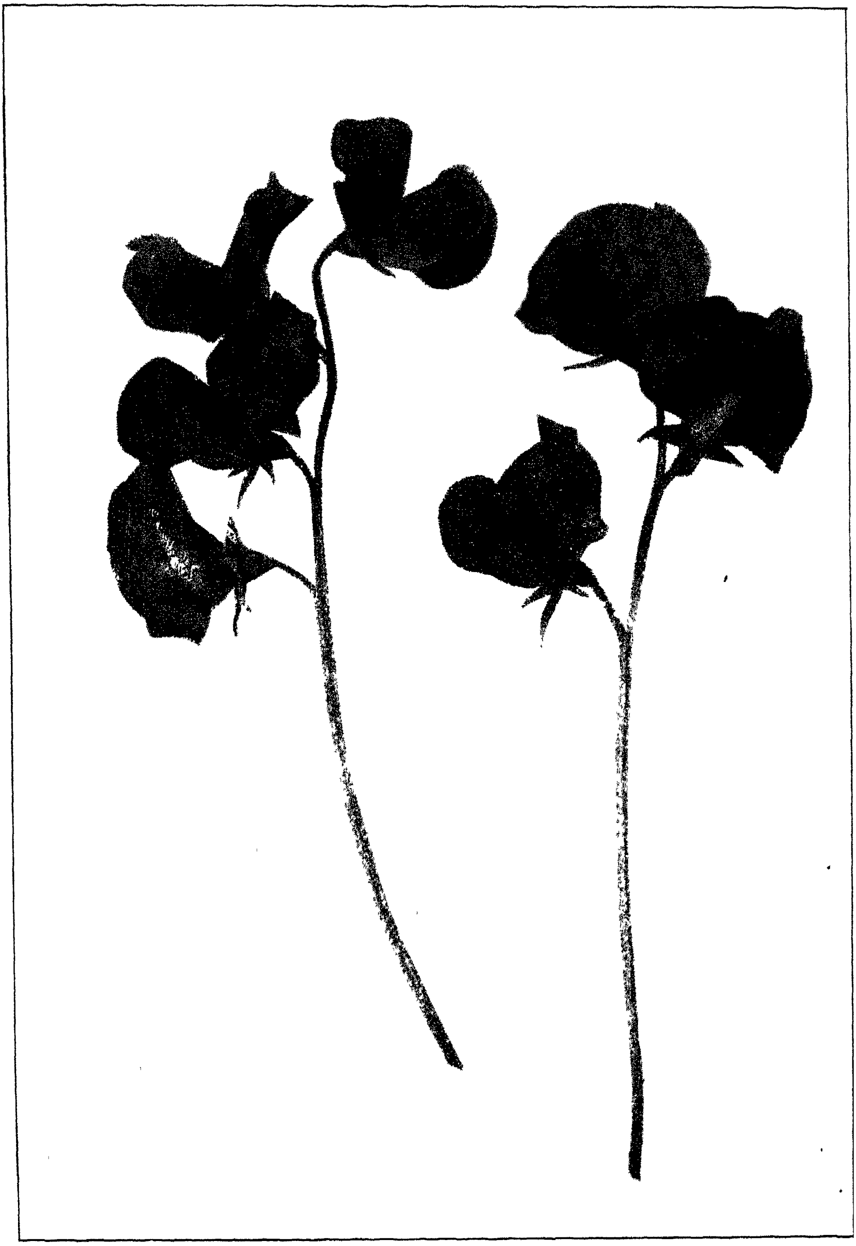
Donated by Dobbie, 1912, 1913.

Description in brief — Large, waved, flushed with pink on a cream ground.

Description in detail — Color of standard fleshy white 9 (4), edges flushed with pale rosy pink 129 (1), brightest on the back; wings fleshy white 9 (1), with more delicate edge of pink. Flower large, waved form; standard large, much waved; wings long and broad, spreading. Flowers on long, strong stems; many doubles. Very fragrant. Very productive. Plant of tall, healthy growth. Tendrils green.



Elaine



Sunproof King

Comparison — At this station this variety was much superior to Paradise Ivory.
Remarks — A very beautiful variety; deserves to be included in all collections.

MAY PERRETT SPENCER

Originated by Malcolm. *Introduced by* Malcolm, 1913.

Donated by Boddington, 1913.
Description in brief — Light pink on a buff ground.
Description in detail — Color of standard and wings light buff, flushed with pink. Flower of medium size, grandiflora form; standard of medium size, erect; wings short and broad, concealing the keel. Flowers two to three, on long, strong stems. No fragrance. Bloom moderate. Sunproof. Plant of tall, slender growth. Leaflets broad, round, dark green.
Synonyms — Is May Perrett.
Remarks — Stock true to type.

PARADISE BEAUTY

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus.
Description in brief — A fairly large, waved variety, of ivory color.
Description in detail — Color rosy white 8 (1–2); wings 8 (3–4). Flower large; standard large, slightly waved; wings medium to large, long and broad, concealing the keel. Flowers two to four, on long, strong stems. Fragrant. Bloom profuse. A garden or market variety. Plant of moderately strong growth. Tendrils colored; color in axils. Seed black.
Comparison — Has more substance and less pink color in the flowers than Paradise Ivory.
Remarks — A fixed stock.

PARADISE IVORY

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1907.

Donated by Miss Hemus, Stark, 1910.
Description in brief — A medium to large, ivory-white, waved variety.
Description in detail — Color fleshy white 9 (1–2). Standard of medium size, slightly waved; wings broad and medium long, concealing the keel. Flowers two to four, usually three, on long, moderately stout stems. Extremely fragrant. Bloom profuse. A home or market variety. Plant of medium height, strong. Color in axils of leaves. Seed black.
Comparison — Lady Knox, a later introduction, surpasses this variety.

PRIMROSE BEAUTY

Originated by Stark. *Introduced by* Stark, 1912.

Donated by Stark, 1912.
Description in brief — A large, waved, primrose variety.
Description in detail — Color of standard and wings yellowish white 13 (2–3). Flower very large, waved form; standard very large, slightly waved; wings long and broad. Flowers three, equidistant on long, strong stems. Moderately fragrant. Plant of very tall, strong growth. Leaflets broad, pointed; tendrils green.
Comparison — Dobbie's Cream opens with more yellow in the flowers. Appears to be Mrs. Collier in Spencer form.
Remarks — The finest variety of this color.

PRIMROSE PARADISE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1908.

Donated by Miss Hemus, 1910.

Description in brief — A large, waved, primrose variety.

Description in detail — Color of standard creamy white 10 (2–3); wings 10 (2). Plant of medium height and strong, healthy growth. Seed white.

Comparison — Similar to Primrose Spencer.

Remarks — A pure stock.

PRIMROSE SPENCER

Originated by L. C. Routzahn. *Introduced by* Burpee, 1908.

Donated by Boddington, Henderson, Morse, Rawson, 1910; Burpee, 1911, 1912, 1913.

Description in brief — A large, waved, primrose variety, for garden, market, or exhibition purposes.

Description in detail — Front of standard yellowish white 13 (2–3), back 13 (4); wings 13 (1–2). Standard large, Spencer-waved; wings very large, long and broad, concealing the keel. Flowers two to four, well arranged on long, strong stems. Moderate fragrance. Bloom profuse, continuous. Plant of tall, vigorous growth. Seed white.

Comparison — Similar to Clara Curtis (Bolton, 1908).

Remarks — The standard variety of this color.

QUEENIE

Originated by Deal. *Introduced by* Deal, 1909.

Donated by Deal, 1910, 1912.

Description in brief — A medium to large, ivory-white, waved variety.

Description in detail — Color of standard shades from rosy white 8 (2–3) to pale rosy pink 129 (2–3) at the edge; wings lilacy white 7 (1–2). Flower large; standard large, slightly waved; wings long and broad, concealing the keel. Flowers two to four, on long, moderately strong stems. Fragrant. Plant of moderate growth. Tendrils green. Seed black.

Comparison — Resembles Paradise Ivory.

Remarks — Badly unfixed in 1910. Fixed stock in 1912.

QUEEN VICTORIA SPENCER

Originated by ————. *Introduced by* Burpee, 1909.

Donated by Morse, 1910; Burpee, 1911, 1912.

Description in brief — A large, waved, black-seeded, primrose variety.

Description in detail — Flower opens lilacy white 7 (4), changing to yellowish white 13 (2–3). Standard large, Spencer-waved; wings long and broad, concealing the keel. Flowers three, on strong stems of medium length. Moderate fragrance. Plant of tall, strong, healthy growth. Seed black.

Comparison — Paradise Ivory is similar.

Remarks — This variety, having dark-colored seed, is selected as the best cream variety, owing to difficulty in germinating varieties having light-colored seed.

SEAFOAM

Originated by Cole. *Introduced by* Cole, 1910.

Donated by Cole, 1910.

Description in brief — A medium to large, ivory-white, waved variety.

Description in detail — Color creamy white 10 (1–2). Standard of medium size, slightly waved; wings long and broad, concealing the keel. Flowers two to four, on long, strong stems. Fragrant. Bloom profuse. A garden or market variety. Plant of moderately strong, healthy growth. Tendrils colored; color in axils of leaflets.

Comparison — The wings are a deeper and brighter pink than those of Paradise Ivory.

Remarks — A fixed stock.

Cream-Pink (Deep)

CONSTANCE OLIVER

Originated by W. Lumley. *Introduced by* Lumley, 1908.

Donated by Dobbie, 1910.

Description in brief — A large, waved, cream-pink variety.

Description in detail — Color of standard peach blossom (pink suffused with cream) 127 (1); wings bright rose 128 (1). Flower very large; standard very large, much waved; wings long and broad, concealing the keel. Flowers two to four, usually three, on long, strong stems. Fragrant. Bloom profuse. Plant of medium height and strong growth. Tendrils colored.

Comparison — Nell Gwynne is similar but is not fixed. Paradise Constance Oliver is an unfixed strain of this variety.

Remarks — A pure stock.

DORIS USHER

Originated by A. E. Usher. *Introduced by* Sutton, 1911.

Donated by Sutton, 1912.

Description in detail — Color of standard rosy pink 118 (1–2); wings rosy pink 118 (2–3). Flower of medium size, waved form; standard of medium size, slightly waved; wings short and broad, spreading. Flowers two to three, equidistant on long, strong stems. Moderately fragrant. Bloom scant. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed; tendrils colored.

Comparison — Smaller than Mrs. Routzahn, but similar to it. Smaller flower, and lighter, softer, more even color, than Constance Oliver.

MARY GARDEN

Originated by Morse. *Introduced by* Morse, 1912.

Description in brief — A large, waved, double, cream-pink variety.

Description in detail — Color of standard rosy pink 118 (1–2); wings same, with tinge of Tyrian rose 155 (1) on edge. Flower very large, waved form; standard very large, much waved, often double; wings long and broad, concealing the keel. Flowers three, irregular on long, slender stems. Moderately fragrant. Sunproof. Plant of tall, slender growth.

Comparison — Burpee called a strain of this variety Duplex Mary Garden.

Remarks — Stock contained color rogues.

MINNIE FURNELL

Originated by W. E. Alsen. *Introduced by* Alsen, 1912.

Donated by Alsen, 1912.

Description in brief — A pale pink, with a cream blotch at base of standard.

Description in detail — Color of standard light rose 128 (1 or lighter), with cream blotch at base; wings light rose 128 (1 inside and 2–3 outside). Flower large, waved form; standard large, slightly waved. Flowers two to three, equidistant on strong stems of medium length. Moderately fragrant. Bloom scant in 1912. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed; tendrils colored.

MIRIAM BEAVER

Originated by Morse. *Introduced by* Burpee, 1910.

Donated by Burpee, Morse, Rawson, 1910.

Description in brief — A large, Spencer-waved variety, of unusual color.

Description in detail — The predominating color was as follows: standard salmon-pink 126 (1–2); wings 126 (1), shading to 126 (2–3) at base. Standard large, Spencer-waved; wings waved, long and broad. Flowers two to four, usually three, on long, strong stems. Fragrance slight. Bloom free. Sunproof. Plant of medium height and stout, healthy growth. Seed large, dark brown.

Comparison — Deeper salmon-pink than Mrs. Routzahn.

Remarks — Very unfixed.

MRS. GIBBS BOX

Originated by James Box. *Introduced by* Box, 1912.

Donated by Box.

Description in brief — Large, waved, rosy pink on a cream ground.

Description in detail — Color of standard rosy pink 118 (1), wings 118 (2–3), on a cream ground. Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Flowers two to three, equidistant on long, strong stems. Little or no fragrance. Moderately productive. Plant of very tall, stout growth. Leaflets broad, pointed; tendrils green.

Comparison — Is a lighter pink and has more cream than Constance Oliver. Has better stem and is more productive than Minnie Furnell.

NATOMA

Originated by Morse. *Introduced by* Morse, 1912.

Donated by Morse, 1912.

Description in brief — A large, salmon-buff, waved variety.

Description in detail — Color of standard pale rosy pink 129 (2–3), inside tinted lilac-rose; wings lilac-rose 152 (1 or lighter), sometimes with violet-rose tints. Flower large, waved form; standard large, waved, sometimes double; wings short and broad, waved. Flowers irregular on very long, strong stems. Moderately fragrant. Moderately productive. Sunproof. Plant of very tall, strong growth. Leaflets broad, pointed.

Comparison — Appears to be a Venus of Spencer form.

NELL GWYNNE

Originated by Stark. *Introduced by* Stark, 1908.

Donated by Stark, 1910.

Description in brief — A large, cream-pink, waved variety.

Comparison — Similar to Constance Oliver.

Remarks — One half or more of this stock were rogues of the color of John Ingman.

OLIVE RUFFELL

Originated by Stark. *Introduced by* Stark, 1908.

Donated by Stark (selected stock), 1910.

Description in brief — A large, waved, rosy salmon variety.

Description in detail — Color of standard shades from lilacy white 8 (4) to bright rose 128 (2–3) at base; wings purple-rose 150 (1). Standard and wings large and waved. Flowers two to four, usually three, on long stems. Fragrant. Bloom profuse. Plant of strong, healthy growth. Tendrils colored; color in axils of leaves.

Comparison — This is a deeper-colored Constance Oliver.

Remarks — Not quite fixed when grown here in 1910.

Cream-Pink (Pale)

BERYL

Originated by Aldersey. *Introduced by* Aldersey, 1912.

Donated by Aldersey (Aldersey's No. 151), 1912.

Description in brief — "A creamy pink self." — Sweet Peas Up to Date.

Description in detail — Color of standard salmon-pink 126 (1); wings bright rose 128 (1–2), brighter on edge. Flower large, waved form; standard large, waved; wings long and broad, spreading. Flowers equidistant on strong stems. Moderately fragrant. Moderately productive. Sunproof. Plant of tall, stout growth.

Comparison — More cream than Constance Oliver and more rosy pink than Doris Usher.

CORONATION

Originated by Bolton. *Introduced by* Bolton, 1912.

Donated by Sydenham, 1913.

Description in brief — A large, pale cream-pink variety.

Description in detail — Color of standard and wings creamy white 10 (1), overlaid with purple-rose 150 (1), the back of the standard is uniform with the color of the front, while the back of the wings is a deeper rose. Flower large, waved form; standard large, waved; wings short and broad, concealing the keel. Flowers three, equidistant, close, on strong stems of medium length. Moderately fragrant. Bloom profuse. Sunproof. Plant of very tall, stout growth. Leaflets broad, dark green; tendrils colored.

Remarks — There are many varieties very nearly like this, yet it is worthy of trial by growers of sweet peas.

ELLA KELWAY

Originated by ————. *Introduced by* Kelway, 1912.

Donated by Kelway, 1912, 1913.

Description in brief — A large, waved, pale cream-pink variety.

Description in detail — Color of standard and wings creamy white 10 (2–3), overlaid and edged with light purple-rose; back of standard lighter in color and without

the edging; back of wings brighter pink. Flower large to very large, waved form; standard large, much waved; wings short and broad, concealing the keel. Flowers three to four, on strong stems of medium length. Very fragrant. Moderately productive. Sunproof. Plant of tall, slender growth. Leaves broad, pointed, dark green.

Remarks — A fine variety, but with such as Mrs. Routzahn, Mrs. Henry Bell, and Mrs. Hugh Dickson there seems no room for it. Stock true to type.

GLADYS BURT

Originated by Unwin. *Introduced by* Unwin, 1908.

Donated by Unwin, 1910.

Description in brief — A very large, waved, salmon-pink variety. Suitable for all purposes.

Description in detail — Color mauve-rose 153 (2–3), on a primrose ground. Flower large to very large; standard large, very waved; wings long and broad, concealing the keel. Flowers three, on long, strong stems. Fragrant. Bloom profuse. Plant of fairly tall, vigorous, healthy growth. Tendrils colored; color in axils of leaves. Seed dark brown, small, round.

Comparison — Color is between that of Mrs. Routzahn and Constance Oliver.

Remarks — A pure stock.

HOLDFAST BELLE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — A large, waved, cream-pink variety.

Comparison — Very similar to Mrs. Routzahn.

Remarks — A pure stock.

JULIET

Originated by Deal. *Introduced by* Deal, 1912.

Donated by Deal, 1912.

Description in brief — Large, waved, rosy pink on a cream ground.

Description in detail — Color of standard rosy pink 118 (1), on a pale yellow ground; wings rosy pink 118 (2). Flower large, waved form; standard large, waved slightly; wings short and broad, spreading. Flowers irregular on long, strong stems. No fragrance. Bloom productive. Sunproof. Plant of tall, strong growth.

Comparison — Less vivid than Mrs. Routzahn at all stages. Worthy of trial because it gives a wider range of color within this group.

LADY MILLER

Originated by Malcolm. *Introduced by* Dobbie, 1913.

Donated by Malcolm, 1912.

Description in brief — "Apricot on cream suffused pink."— Dobbie's catalogue.

Description in detail — Color of standard and wings shrimp pink 75 (1 or lighter). Flower large, waved form; standard large, slightly waved, sometimes double; wings long and broad, concealing the keel. Flowers three to four, irregular on long, strong stems. Moderately fragrant. Productive. Sunproof. Plant of tall, slender growth. Petioles and calyx brownish; tendrils colored.

Comparison — Better than Cherub. Not so large nor so much waved as Constance Oliver.

Remarks — Stock pure, true.

MRS. HENRY BELL

Originated by Bolton. *Introduced by* Bolton, 1908.

Donated by Rohnert, 1912.

Description in brief — Large, waved, rich pink on a cream ground.

Description in detail — Color of standard bright rose 128 (1), with cream base; wings 128 (1), with considerable lilac-rose on the edges. Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Substance good. Flowers two to three, irregularly spaced on strong stems of medium length. Moderately fragrant. Bloom profuse. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Comparison — More purplish pink than Mrs. Routzahn and not so much pink as Holdfast Belle.

MRS. HUGH DICKSON

Originated by Dobbie. *Introduced by* Dobbie, 1910.

Donated by Dobbie, 1910; Burpee, 1911; Morse, 1912.

Description in brief — A very large, cream-pink, waved variety.

Description in detail — Color of standard lilac-rose 130 (1) on a creamy white ground; wings salmon-pink 128 (1). Standard very large and very waved; wings long and broad, partly open. Substance good. Flowers three to four, on long, strong stems. Fragrant. Bloom free. Plant of strong growth. Seed large, round, black.

Comparison — This variety is earlier and has lighter primrose color than Mrs. Routzahn.

Remarks — A true stock. Commended.

MRS. ROUTZAHN

Originated by ——————. *Introduced by* Burpee, 1909.

Donated by Boddington, Burpee, Morse, 1910; Burpee, 1911, 1912.

Description in brief — A very large, cream-pink Spencer, suitable for all purposes.

Description in detail — Color pale lilac-rose 130 (2) on a yellowish white ground. Standard very large and very waved; wings long and broad, partly open. Flowers two to four, usually three, gracefully placed on long, strong stems. Fragrant. Bloom profuse, continuous. Plant of medium height and strong, healthy growth. Color in axils of leaves.

Remarks — All stocks pure. The standard variety of this color.

MRS. STEWART CHAMPION

Originated by Bide. *Introduced by* Bide, 1911.

Donated by Bide, 1912.

Description in brief — A large, waved, cream-pink self.

Description in detail — Color of standard crushed strawberry 109 (1); wings Rose Neyron red 119 (1). Flower large, waved form; standard large, waved; wings long and broad, spreading. Flowers three, irregularly spaced on long, strong stems. Moderately fragrant. Productive. Sunproof. Plant of very tall, strong growth. Leaves very dark green; leaflets broad, often round; tendrils green.

Comparison — A superior strain of Mrs. Routzahn.
Remarks — A true stock.

QUEEN MARY

Originated by King. *Introduced by* King, 1910.

Donated by King, 1913.
Description in brief — A large, waved, cream-pink variety.
Description in detail — Color of standard creamy white 10 (1), overlaid with lilac-rose 130 (1); wings salmon-pink 128 (1). Flower large, waved form; standard large, waved; wings short and broad, concealing the keel. Flowers three, equidistant, close, on strong stems of medium length. Moderately fragrant. Bloom profuse. Sunproof. Plant of tall, stout growth. Leaflets broad, rounded, dark green.

SUTTON'S QUEEN

Originated by T. Rothera & Co. *Introduced by* Sutton, 1908.

Donated by Boddington, 1910; Sutton, 1912.
Description in brief — Medium to large, slightly waved variety.
Description in detail — Color pale lilac-rose 130 (1) on creamy white 10 (1), changing to almost white. Standard medium to large, slightly waved; wings of medium size, partly open. Flowers two to three, on medium stems. Moderate fragrance. Bloom not continuous. Plant below medium height, healthy.
Comparison — Inferior to Mrs. Routzahn.
Remarks — A mixed stock containing some plants of the color of E. J. Castle and Stella Morse in 1910. A pure stock from introducers in 1912.

W. T. HUTCHINS

Originated by ——————. *Introduced by* Burpee, 1910.

Donated by Burpee, Morse, 1910.
Description in brief — A large, cream-pink, waved variety.
Description in detail — Color yellowish white 13 (4), flushed with pale lilac-rose 130 (2–3), with deeper shade around the edges. Standard large, waved; wings long and broad, waved, concealing the keel. Flowers three, on long, strong stems. Fragrant. Plant of tall, strong growth. Color in axils of leaves. Seed black.
Remarks — One stock produced flowers with more pink color.

Crimson

CAPTIVATION SPENCER

Originated by Morse. *Introduced by* Morse, Burpee, 1912.

Donated by Burpee, Boddington, 1912.
Description in brief — "A rich rosy wine red."— Sweet Peas Up to Date.
Description in detail — Color of standard amaranth-red 168 (1–3); wings rosy magenta 169 (1–2), veined darker. Flower large, waved form; standard large, slightly waved; wings long and broad, spreading or drooping. Substance good. Flowers two, on slender stems of medium length. Slightly fragrant. Not productive. Plant of medium height and slender growth. Leaflets broad, pointed; tendrils green.
Comparison — Similar to Rosie Adams.

CRIMSON GIANT

Originated by Deal. *Introduced by* Deal, 1911.

Donated by Deal, 1912.

Description in detail — Color of standard crimson-red 114 (1–2), veined darker; wings crimson-red 114 (1–2), with a slight purplish tinge. Flower large, waved form; standard large, slightly waved; wings large, long and broad. Flowers two to three, on strong stems of medium length. Slightly fragrant. Moderately productive. Burns slightly. Plant of tall, stout growth. Leaflets broad, pointed.

Comparison — Is more crimson and burns more than King Edward Spencer.

CRIMSON PARADISE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1909.

Donated by Miss Hemus, 1910.

Description in brief — A large, waved, crimson, all-purpose variety.

Description in detail — Color of standard carmine-purple 156 (3–4); wings 156 (1). Flower large to very large; standard very large, Spencer-waved; wings long and broad. Flowers two to four, on long, strong stems. Slight fragrance. Bloom profuse, continuous. Not sunproof. Plant of tall, vigorous growth.

Comparison — Superior to any of the strains of King Edward Spencer, except that it is not sunproof.

G. C. WAUD

Originated by Cole. *Introduced by* Cole, 1910.

Donated by Cole, 1910.

Description in brief — A large, waved, crimson-scarlet, garden variety.

Description in detail — Color of standard carmine-purple 156 (1–2); wings 156 (1). Standard large, slightly waved; wings large, waved, partly open. Flowers three, on long, strong stems. Moderate fragrance. Bloom profuse. Burns slightly. Plant of strong, healthy growth. Seed large and black.

Comparison — Similar to King Edward Spencer.

Remarks — Stock not fixed; contained one plant of John Ingman and one of Coccinea.

KING EDWARD SPENCER

Originated by ——————. *Introduced by* Burpee, 1909.

Donated by Boddington, Burpee, Morse, Unwin, 1910; Burpee, 1911, 1912.

Description in brief — A large, carmine-scarlet, waved, garden or market variety.

Description in detail — Color of standard carmine-purple 156 (3–4); wings 156 (1). Standard large, moderately waved; wings very long and broad, not waved, concealing the keel. Flowers two to four, usually three, on long, strong stems. Very slight fragrance. Bloom profuse, continuous. Plant of tall, strong, healthy growth.

Comparison — The King is of superior form but is less resistant to the sun.

Remarks — All strains pure. Finest strains from Burpee and Morse.

LIBERTY

Originated by ——————. *Introduced by* Lumley, 1910.

Donated by Farquhar, 1913.

Description in detail — Color of standard crimson-red 114 (1–2), veined darker; wings amaranth-red 168 (1–2), turning crimson, slightly darker on back. Flower large,

waved form; standard large, slightly waved; wings large, long and broad, concealing the keel. Flowers three, on short stems. No fragrance. Moderately productive. Burns. Plant of medium height and slender growth. Leaflets broad, round, dark green; tendrils green.

Remarks — Stock pure, true.

MRS. DUNCAN

Originated by Stark. *Introduced by* Stark, 1910.

Donated by Stark, 1910; Boddington, 1912.

Description in brief — A large, waved, crimson, garden or market variety.

Description in detail — Color of standard crimson-red 114 (2–3); wings carmine-purple 156 (1). Standard large to very large, moderately waved; wings long and broad, concealing the keel. Flowers two to four, usually three, on long, strong stems. Very slight fragrance. Bloom profuse, continuous. Nearly sunproof. Plant of tall, strong, healthy growth.

Comparison — Not waved so much as the strains of The King.

Remarks — A fixed stock. Some flowers showed signs of burning, but did not blacken.

ORION

Originated by Holmes. *Introduced by* Sydenham, 1912.

Donated by Sydenham, 1912.

Description in brief — " A large, deep reddish crimson."— Sweet Peas Up to Date.

Description in detail — Color of standard and wings lilac-purple 160 (2–3). Flower large, waved form; standard large, slightly waved; wings short and broad, spreading. Flowers three, irregularly placed on stems of medium length. Moderate fragrance. Moderately productive. Sunproof. Plant of tall, strong growth. Leaflets broad.

ROSIE ADAMS

Originated by Thomas Stevenson. *Introduced by* Stevenson, H. J. Wright, 1908.

Donated by Farquhar, 1913.

Description in detail — Color of standard amaranth-red 168 (1–2); wings amaranth-red to deep purple; both standard and wings veined darker. Flower medium to large, waved form; standard large, waved; wings short and broad, concealing the keel. Flowers three, irregular on long, strong stems. No fragrance. Bloom profuse. Sunproof. Plant of tall, stout growth. Leaflets broad, pointed, dark green; tendrils green.

Comparison — Similar to Captivation Spencer.

Remarks — Stock mixed, one white rogue.

RUBY PALMER

Originated by ——————. *Introduced by* Dobbie, 1914.

Donated by Dobbie, 1912.

Description in detail — Color of standard and wings lilac-purple 160 (4), inside of wings shading 160 (1–2). Flower large, waved form; standard large, slightly waved, with slightly auriculate base; wings large, long and broad. Substance good. Flowers three, on medium stems. Moderately fragrant. Moderately productive. Sunproof.

Comparison — A trifle more purplish than King Edward Spencer. Darker than Marie Corelli.

SUNPROOF KING

Originated by Bide. *Introduced by* Bide, 1910.

Donated by Bide, 1910.

Description in brief — A very large variety, for garden, market, or exhibition use.

Description in detail — Color of standard carmine-purple 156 (3–4); wings 156 (1). Standard very large, much waved; wings long and broad, waved, partly open. Flowers two to four, on long, strong stems. Mild fragrance. Bloom profuse, continuous. Sunproof. Plant of strong, vigorous growth.

Remarks — A fixed stock. Everything considered, this was the finest strain of this color in 1910.

THE KING

Originated by Dobbie. *Introduced by* Dobbie, 1909.

Donated by Dobbie, 1910.

Description in brief — A very large, waved variety.

Description in detail — Color of standard carmine-purple 156 (3); wings 156 (1). Standard very large, very waved; wings large, waved, partly open. Flowers three, equidistant on long, strong stems. Very slight fragrance. Plant of vigorous, healthy growth.

Comparison — Superior to King Edward Spencer in size and form, but the flowers turn black under a hot sun.

Remarks — A fixed stock.

Fancy

AFTERGLOW

Originated by Bolton. *Introduced by* Bolton, 1911.

Donated by Burpee, 1913.

Description in brief — Reddish mauve, with violet wings.

Description in detail — Color of standard purplish mauve 186 (4 or darker); wings bright violet 198 (2–3). Flower large, waved form; standard large, much waved; wings long and broad, concealing the keel. Flowers three to four, equidistant, close, on strong stems of moderate length. Moderately fragrant. Moderately productive. Sunproof. Plant of medium height and stout, healthy growth. Leaflets broad, pointed, dark green; tendrils clinging.

CHARLES FOSTER

Originated by Bolton. *Introduced by* Bolton, 1911.

Donated by Burpee, 1913.

Description in brief — " Pastel pink shaded lavender."— Sweet Peas Up to Date.

Description in detail — Color bright rose 128 (1–2) flushed with lavender, deeper at base; wings bright rose 128 (1–2), with less lavender. Flower large, waved form; standard large, waved, with round top and broad base; wings large, long and broad, concealing the keel. Flowers three to four, equidistant, close, on short, strong stems. Moderately fragrant. Moderately productive. Burns slightly. Plant of medium height and stout, healthy growth. Leaflets broad, pointed, dark green.

Remarks — Stock pure, true to type.

Lavender

ASTA OHN

Originated by Henry Ohn. *Introduced by* Morse, 1909.
Donated by Morse, Rawson.
Description in brief — Large, waved, lavender suffused with mauve.
Description in detail — Standard purplish mauve 186 (1–2), changing to ageratum blue 201 (2); wings pale light lilac 187 (1), changing to Parma violet 200 (3–4). Standard large, waved; wings very large, waved, long and broad, concealing the keel. Flowers two to three, on strong stems of medium length. Fragrant. Bloom profuse, continuous. A garden and market variety. Plant of medium height and stout, healthy growth. Seed mottled.
Comparison — At this station this variety always has more mauve color than Frank Dolby, although it changes to blue.

BERTRAND W. DEAL

Originated by Deal. *Introduced by* Deal, 1910.
Donated by Deal, 1911.
Description in brief — A waved, rosy mauve variety.
Description in detail — Color of standard pale lilac-rose 178 (2–3); wings pale light lilac 187 (1). Flower very large, waved form; standard very large, much waved; wings very large, long and broad, spreading. Flowers three, on very long stems of medium strength. Moderately fragrant. Moderately productive. Plant of moderately tall, slender growth. Leaflets broad, pointed; tendrils green.

DORA

Originated by ————. *Introduced by* Bath.
Donated by Bath, 1912.
Description in brief — A waved, lavender variety.
Description in detail — Color of standard bishop's violet 189 (1–2), veined with light violet 198 (3–4); wings bright violet 198 (1). Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Flowers on medium, slender stems. Very fragrant. Moderately productive. Burns slightly and is badly injured by wet weather. Plant of tall, strong growth. Leaflets broad, pointed.
Comparison — Similar to Asta Ohn.

DRAGONFLY

Originated by Aldersey. *Introduced by* Aldersey, 1913.
Donated by Aldersey, 1912.
Description in brief —" Lavender on cream ground, wings lavender."— Sweet Peas Up to Date.
Description in detail — Color of standard and wings bright violet 198 (1), with a rosy tinge. Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Substance poor. Flowers two to three, on long stems. Moderately fragrant. Bloom moderate. Plant of tall, strong growth.

FELICITY

Originated by ————. *Introduced by* Bath, 1913.
Donated by Bath, 1912.
Description in brief — " A large waved lilac, flushed pink."— Introducer's description.

Description in detail — Color of standard and wings heliotrope 188 (1–2); standard sometimes darker on back near base. Flower of medium size, waved form; standard of medium size, slightly waved; wings long and broad. Substance poor. Flowers three, on strong stems of medium length. Moderate fragrance. Bloom medium. Sun fades badly. Plant of tall, strong growth.
Comparison — Lighter than Tennant Spencer. Distinct from Irish Belle.

FLORENCE NIGHTINGALE

Originated by Hugh Dickson. *Introduced by* Burpee, 1911.
Donated by Burpee, 1911, 1912, 1913.
Description in brief — A large, waved, clear lavender self.
Description in detail — Color of standard bright violet-purple 190 (1–2); wings light bluish violet 202 (3–4). Flower large, waved form; standard large, slightly waved; wings long and narrow. Flowers three to four, irregularly spaced on long, strong stems. Moderately fragrant. Bloom profuse. Plant of tall, slender growth.
Remarks — A worthy variety.

FRANK DOLBY

Originated by Unwin. *Introduced by* Unwin, and Watkins & Simpson, 1907.
Donated by Boddington, Rawson, Unwin, and Watkins & Simpson.
Description in brief — A fairly large, lavender variety of Unwin form.
Description in detail — Standard opens violet-mauve 195 (1–2), changing to Parma violet 200 (1–3); wings open lilac-mauve 199 (1), changing to ageratum blue 201 (1–2). Standard large, slightly waved; wings large. Flowers two to four, on long, strong stems. Fragrant. Bloom very profuse, continuous. A garden or market variety. Plant of medium height and strong, vigorous growth. Color in axils of leaves. Seed dark brown, mottled, small to medium in size.

FRANK UNWIN

Originated by Unwin. *Introduced by* Unwin, 1910.
Donated by Unwin, 1910.
Description in brief — A large, waved variety, soft lavender suffused with mauve.
Description in detail — Color of standard bluish lilac 183 (1–2); wings heliotrope 188 (2–3). Standard large, Spencer-waved; wings of medium size, waved, short and broad. Flowers two to three, on stems of medium length and strength. Fragrant. Bloom profuse. A garden variety. Plant of medium height and slender growth. Seed dark brown, of medium size.
Comparison — This variety is distinct from Frank Dolby.
Remarks — A fixed stock. Late in the season some flowers are mottled.

IRISH BELLE

Originated by Dickson. *Introduced by* Burpee, 1912.
Donated by Burpee, 1912.
Description in brief — " Rich lilac flushed pink."— Burpee's catalogue.
Description in detail — Color of standard and wings purplish mauve 186 (1–2). Flower large, waved form; standard large, slightly waved; wings large, long and broad. Flowers three, irregularly spaced on long stems of medium strength. Moderate fragrance. Moderately productive. Burns slightly. Plant of medium height and slender growth. Tendrils green.

Comparison — Lighter than Florence Nightingale or Mauve Queen, and darker than Felicity or Orchid.
Synonyms — Dream is another name for this variety.
Remarks — Received award of merit from American Sweet Pea Society in 1911.

IVANHOE

Originated by Dobbie. *Introduced by* Dobbie, 1911.
Donated by Dobbie, 1912.
Description in brief — Soft heliotrope-mauve.
Description in detail — Color of standard purplish mauve 186 (1–2), shading into heliotrope 188 (1) in center; wings heliotrope 188 (1). Flower very large, waved form; standard very large, much waved, slightly auriculate; wings large, long and broad. Substance good. Flowers three, equidistant on long, strong stems. Very fragrant. Bloom profuse, continuous. Sunproof. Plant of tall, stout growth. Leaflets broad, pointed.
Comparison — Is lighter mauve and has more heliotrope than Betty. Larger and paler than Tennant Spencer.

LAVENDER QUEEN

Originated by ————. *Introduced by* Dobbie.
Donated by Dobbie, 1912.
Description in brief — A very large, waved, lavender variety.
Description in detail — Color of standard bright violet 198 (1), flaked darker; wings ageratum blue 201 (1). Flower very large, waved form; standard very large, much waved; wings large, long and broad. Substance good. Flowers three to four, equidistant on long, strong stems. Very fragrant. Bloom profuse. Plant of tall, stout growth. Leaflets broad, pointed; tendrils green.
Comparison — Has more lavender and is of slightly better growth than Asta Ohn. Is similar to Florence Nightingale.

LAVENDER SPENCER

Originated by Stark. *Introduced by* ————.
Donated by Stark, for advance trial, 1910.
Description in brief — A moderately large, waved, lavender variety.
Description in detail — Color of standard heliotrope 188 (1–2); wings 188 (1). Standard moderately large, Spencer-waved; wings waved, long and broad. Flowers two to three, on long, strong stems. Fragrant. Bloom profuse. Plant of medium height and slender, healthy growth. Tendrils colored; color in axils of leaves. Seed mottled.
Remarks — A pure stock.

LILAC QUEEN

Originated by Bath. *Introduced by* Bath, 1910.
Donated by Bath, 1910.
Description in brief — A lilac variety, of Unwin form and size.
Description in detail — Standard purplish mauve 186 (2–3); wings 186 (1). Flower medium large; standard medium large, Unwin type, erect; wings medium, hooded, long and broad, concealing the keel. Flowers two, on long stems of medium strength. Fragrant. Bloom profuse. Sunproof. A garden variety. Plant of medium height and moderately strong, healthy growth. Seed small, wrinkled.
Remarks — A fixed stock.

MALCOLM'S NO. 14

Originated by Malcolm. *Introduced by* ————.

Donated by Dobbie, 1912.

Description in brief — A very large, waved, heliotrope and bluish violet variety.

Description in detail — Color of standard heliotrope 188 (3–4); wings light bluish violet 202 (1). Flower very large, waved form; standard very large, often much waved, with broad base; wings large, long and broad. Substance good. Flowers three, irregularly placed on strong stems of medium length. Not fragrant. Bloom moderate. Sunproof. Plant of tall, stout, healthy growth. Leaflets broad, pointed; tendrils green.

Comparison — Less mauve than Asta Ohn. Similar to Florence Nightingale.

MANDOLINE

Donated by Dobbie, 1912.

Description in brief — A very large, reddish lavender flower.

Description in detail — Color of standard and wings bright violet 198 (1–2). Flower very large, waved form; standard very large, often double, slightly waved, with slightly auriculate base; wings very large, long and broad. Substance good. Flowers three, equidistant on long stems of medium strength. Moderate fragrance. Bloom profuse. Plant of medium height and slender growth.

Comparison — Similar to Asta Ohn.

MASTERPIECE

Originated by Malcolm. *Introduced by* Dobbie, 1910.

Donated by Dobbie, 1910.

Description in brief — Large, pinkish or purplish mauve, changing to lavender, waved.

Description in detail — Standard opens purplish mauve 186 (1), with edge of 186 (2–3); wings open heliotrope 188 (2); flower changes soon to Parma violet 200 (1); introducer says, " color is 201 (1) but paler." Standard large, Spencer-waved; wings large, waved, partly open, long and broad. Flowers two to four, on strong stems of medium length. Moderately fragrant. Bloom free, continuous. Plant of tall, strong, vigorous growth. Seed small, mottled.

Remarks — A pure stock.

MAUVE BEAUTY

Originated by ————. *Introduced by* Box.

Donated by Box, 1912.

Description in detail — Color of standard purplish mauve 186 (2–3), with violet tint on back and toward base; wings bright violet 198 (1–2), often splashed darker. Flower large, waved form; standard large, often double, slightly waved; wings long and broad, spreading. Substance good. Flowers two to three, on medium to long, slender stems. Moderately fragrant. Bloom profuse. Plant of tall, slender growth. Leaflets broad, pointed; tendrils green.

Comparison — Similar to Asta Ohn and Florence Nightingale.

MAUVE SPENCER

Donated by Burpee, for advance trial, 1910.

Description in brief — A large, waved, mauve variety.

Description in detail — Color of standard varies from violet-mauve 195 (1) to lilac-mauve 196 (1); wings 196 (4). Standard very large, Spencer-waved; wings very

large, waved, long and very broad. Flowers two to three, on long, strong stems. Bloom profuse. An exhibition variety. Plant of tall, stout growth. Tendrils colored; color in axils of leaves.

Comparison — Would supplant Frank Dolby.

Remarks — Unfortunately not fixed.

MRS. CHARLES FOSTER

Originated by Bakers. *Introduced by* Bakers, 1907.

Donated by Dobbie, 1910.

Description in brief — Large, lavender flushed with rose, waved.

Description in detail — Color of standard purplish mauve 186 (2), back heliotrope 188 (2–3); wings heliotrope 188 (2). Standard large, moderately waved; wings large, long and broad, partly open. Flowers two to three, on very long, strong stems. Fragrant. Bloom profuse. Plant of strong, tall growth. Germination poor.

Comparison — Here this variety was distinct this year from Frank Dolby, Masterpiece, and Asta Ohn.

Remarks — A fixed stock.

MRS. REGINALD HILL

Originated by ————. *Introduced by* King, 1913.

Donated by King, 1913.

Description in brief — " A lilac lavender."— King's catalogue.

Description in detail — Color of standard bluish lilac, overlaid with violet 183 (1), deeper at base; wings vinous-mauve 184 (1 or lighter), edged with bluish lilac. Flower of medium size, waved form; standard of medium size, slightly waved; wings short and broad, concealing the keel. Flowers two to three, equidistant, close, on medium stems. Not fragrant. Bloom profuse. Sunproof. Plant of tall, slender growth. Leaflets dark green, broad, pointed; tendrils green.

MOONSTONE

Originated by Aldersey. *Introduced by* Aldersey, 1911.

Donated by Aldersey, 1912.

Description in brief — A pale heliotrope.

Description in detail — Color of standard lilac 187 (2–3) to heliotrope at the base; wings heliotrope 188 (1–2). Flower large, waved form; standard large, often double, slightly waved; wings long and broad, spreading. Substance poor. Flowers two to three, irregularly spaced on slender stems of medium length. Fragrance moderate. Moderately productive. Plant tall, slender. Leaflets narrow, pointed; tendrils green.

Comparison — Similar to Nettie Jenkins.

NETTIE JENKINS

Originated by Unwin. *Introduced by* Unwin, 1911.

Donated by Unwin, for advance trial, 1910.

Description in brief — A large, waved, lavender, garden or exhibition variety.

Description in detail — Standard opens purplish mauve 186 (1), tinted faint blue; wings violet 200 (3); flower loses the pinkish color, becoming a very light lavender

200 (1–3). Flowers two to three, on long, strong stems. Fragrant. Bloom profuse, continuous. Plant of medium height and strong, healthy growth. Seed dark brown, small, irregular or wrinkled.

Comparison — Belongs to the Frank Dolby group, but is quite distinct.

Remarks — A pure stock.

ORCHID

Originated by Malcolm. *Introduced by* Burpee, 1913.

Donated by Burpee, 1912.

Description in brief — Large, waved, lavender suffused with pink.

Description in detail — Color of standard purplish mauve 186 (1 or lighter), flushed with violet; wings heliotrope 188 (1 or lighter). Flower large, waved form; standard large, slightly waved; wings short and broad, concealing the keel. Flowers three to four, equidistant, close, on medium stems. Very fragrant. Productive. Sunproof. Leaflets broad, round, dark green; tendrils green.

PEARL GREY

Originated by Morse. *Introduced by* Burpee, Morse, 1912.

Donated by Burpee, Boddington, 1912.

Description in brief — " A dove grey suffused light rose."— Burpee's catalogue.

Description in detail — Color Parma violet 200 (1–2). Flower very large, waved form; standard very large, much waved; wings large, long and broad, spreading. Substance good. Flowers three, on long stems of moderate strength. Very fragrant. Bloom profuse. Plant of very tall, stout growth.

Comparison — Seems to be a paler form of Orchid.

Remarks — Variety not fixed in 1912 or in 1913.

PRINCESS ALICE SPENCER

Originated by Routzahn. *Introduced by* Bath, 1909.

Donated by Vick, 1910.

Description in brief — Flower large. Described in catalogue as light lavender, tinted with white.

Description in detail — Standard large, slightly waved; wings large, hooded, long and broad, concealing the keel. Flowers two to three, nearly always three, on long, strong stems. Fragrant. Bloom profuse, continuous. A garden variety. Plant of medium height and strong, healthy growth. Seed small, mottled.

Remarks — Very unfixed, since it contains all shades of lavender with a few white flowers.

QUEEN OF MAUVES

Originated by Sutton. *Introduced by* Sutton, 1913.

Donated by Sutton, 1912.

Description in detail — Color of standard violet-mauve 195 (1), with more mauve on back; wings bluish violet 199 (1 or lighter). Flower large; standard slightly waved, with broad base; wings large, long and broad. Substance good. Flowers three, irregularly placed, but facing one way, on stems of medium length. Moderate fragrance. Bloom profuse. Sunproof. Plant of medium height, slender. Leaflets narrow, pointed; tendrils green.

Comparison — Has more lavender and shorter stems than Dorothy Tennant.

WALTER P. WRIGHT

Originated by Unwin. *Introduced by* Unwin, 1912.

Donated by Sydenham, Unwin, 1913.

Comparison — Similar to Winifred Unwin (described below).

WINIFRED UNWIN

Originated by Unwin. *Introduced by* Unwin, 1912.

Donated by Unwin, 1913.

Description in detail — Color of standard lavender-blue 204 (1 or lighter), with lighter color on back; wings same as standard. Flower large, waved form; standard large, slightly waved; wings short and broad, concealing the keel. Flowers three to four, irregularly spaced, close, on long, strong stems. Moderately fragrant. Bloom profuse. Sunproof. Plant of very tall, strong growth. Leaflets broad, rounded, dark green; tendrils green.

Comparison — Similar to Walter P. Wright, and both are similar to Dobbie's True Lavender, a variety approved by the National Sweet Pea Society of England.

Magenta

MARKS TEY

Originated by Dobbie. *Introduced by* Dobbie, 1913.

Donated by Dobbie, 1912, 1913.

Description in brief —A large, bicolor variety, with rosy maroon standard and purple-violet wings.

Description in detail — Color of standard reddish violet 180 (1–4); wings bright violet-purple 190 (1–2). Flower very large, often double, waved form; standard very large, slightly waved; wings large, long and broad. Flowers three, on strong stems of moderate length. Moderately fragrant. Moderately productive. Burns slightly. Plant of medium height, stout. Leaflets broad, pointed; tendrils green.

Comparison — Slightly more red than Sutton's Royal Purple.

Remarks — This is placed in bicolor section in English lists. In general effect it belongs here.

MENIE CHRISTIE

Originated by Dobbie. *Introduced by* Dobbie, 1908.

Donated by Dobbie, 1910; Rohnert, 1912; Burpee, 1913.

Description in brief — A large, waved, magenta variety.

Description in detail — Color of standard magenta 182 (2–4), veined darker; wings magenta with a violet tinge, to violet-purple 192 (1). Flower large, waved form; standard large, much waved; wings long and broad, spreading. Substance good. Flowers three, on slender stems of medium length. Very fragrant. Bloom profuse. Sunproof. Plant of tall, stout growth. Leaflets broad, pointed.

PURPLE

Originated by Malcolm. *Introduced by* ———————.

Donated by Malcolm, Dobbie, 1912.

Description in brief — A large, waved, reddish violet and deep purple variety.

Description in detail — Color of standard reddish violet 180 (3–4); wings deep purple 185 (1–2). Flower large, waved form; standard large, often double, slightly

waved; wings long and broad. Flowers two to four, on long, strong stems. Moderately fragrant. Moderately productive. Wet weather injures flowers badly. Plant of medium height and stout growth. Leaflets broad, pointed.

Comparison—Similar to Marks Tey and Menie Christie, but not so large nor so profuse in bloom. Produced more doubles than either of the above.

ROYAL PURPLE

Originated by ————. *Introduced by* Sutton, 1912.

Donated by Sutton, 1912.

Description in brief — A large, waved, purple variety.

Description in detail — Color of standard deep purple 185 (2–3); wings bright violet-purple 190 (1). Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Flowers three, on long stems of medium strength. Very fragrant. Moderately productive. Burns slightly. Plant of tall, slender growth. Leaflets broad, pointed; tendrils colored.

Comparison — Less red than Marks Tey.

Marbled

MAY CAMPBELL

Originated by Dobbie. *Introduced by* Dobbie, 1912.

Donated by Dobbie, 1912, 1913.

Description in detail—Color marbled on standard is Tyrian rose 155 (1), on a creamy white 10 (2) ground; wings slightly veined with the same color. Flower large, waved form; standard large, much waved; wings long and broad, spreading. Substance good. Flowers three, on long, strong stems. Moderately fragrant. Moderately productive.

Comparison — Is larger than Aurora Spencer.

Remarks — A very distinct variety. One of the commended varieties of 1912. Deserves a place on every list.

SWEET LAVENDER

Originated by Bath. *Introduced by* Bath, 1910.

Donated by Bath, 1910.

Description in brief — " White ground, marbled lavender, charming flower; fixed."—Introducer's description.

Remarks — This variety proved to be of two shades of red in equal proportions.

Maroon

ANNABEL LEE

Originated by Alsen. *Introduced by* Alsen, 1913.

Donated by Alsen, 1912.

Description in brief — "A pale lilac almost white in center."— Originator's description.

Description in detail — Color of standard dull purple-lake 170, with violet veining and shading at base; wings reddish violet 180 (1–2). Flower large, waved form; standard large, much waved; wings large, long and broad, spreading. Flowers three, irregular on long, strong stems. Fragrance moderate. Productive. Burns badly. Plant of tall, strong, healthy growth. Leaflets broad.

Remarks — One cream-pink rogue. Apparently this did not give us the true-colored variety.

BRONZE PARADISE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — A waved maroon self.

Description in detail — Color of standard deep purple 185 (4); wings 185 (1). Flower of medium size; standard of medium size, generally flat; wings partly open, long and narrow. Flowers two to three, on long stems of fair strength. Growth moderate. Plants were not healthy.

Comparison — Differs from Paradise Maroon in having wings of the same color as the standard.

Remarks — A fixed variety as to color.

CHARLES HEMUS

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — Originator described the variety as a red-mahogany self.

Description in detail — Color of standard amaranth-red 168 (4); wings rosy magenta 169 (1), keel colored a lighter shade. Flower large; standard large and slightly waved; wings long and narrow. Flowers two to three, on long stems of moderate strength. Fragrance moderate. Plant of medium height and slender growth. Foliage blue-green; calyx and pedicel blue-black. Seed dark brown, large, round.

Comparison —Does not closely resemble Black Knight in color.

Remarks — A fixed stock. A distinct variety. Flowers turn darker with age.

CYRIL UNWIN

Originated by Unwin. *Introduced by* Unwin, 1912.

Donated by Unwin, 1913.

Description in brief — Deep purple shaded with maroon, waved.

Description in detail— Color of standard deep purple 185 (1), shaded with maroon, base bright violet-purple; wings bright violet-purple 191 (1–2), varying to light pansy-violet. Flower large, waved form; standard large, much waved; wings short and broad, concealing the keel. Flowers three to four, irregularly spaced on long, strong stems. Moderately fragrant. Bloom moderate. Sunproof. Plant of tall, strong growth. Leaflets broad, round, dark green; tendrils green.

DOUGLAS UNWIN

Originated by Unwin. *Introduced by* Unwin, 1910.

Donated by Unwin, 1910.

Description in brief — A large, waved variety.

Description in detail — Color plum-violet 172 (4). Standard large, slightly waved; wings waved, concealing the keel. Flowers three, on strong stems of medium length. Fragrance moderate. Plant moderately vigorous. Leaves narrow, pointed. Seed black.

Comparison — Similar to Othello Spencer, but not so good a strain.

Remarks — Stock mixed.

GARNET SPENCER

Originated by ——————. *Introduced by* Henderson, 1910.

Donated by Henderson, 1910.

Description in brief — A very large, maroon, waved variety, fine for exhibition.

Description in detail — Color of standard plum-violet 172 (1–2); wings deep carmine-violet 174 (1–2). Standard very large, much waved; wings very long and broad, waved, concealing the keel. Flowers three, on long, strong stems. Moderately fragrant. Bloom profuse, continuous, lasts well on plant. Sunproof. Plant of tall, stout, healthy growth.

Comparison — A fine strain of Othello Spencer, but unfixed.

Remarks — Very much mixed, containing five varieties of waved form.

KING MANOEL

Originated by Stark. *Introduced by* Stark, 1912.

Donated by Stark, 1912.

Description in brief — A large, waved, dark maroon variety.

Description in detail — Color of standard plum-violet 172 (1), veined darker; wings deep purple 185 (3–4). Flower very large, waved form; standard very large, slightly waved; wings very large, long and broad, spreading. Substance good. Flowers three, close together on long, strong stems. Moderately fragrant. Moderately productive. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Comparison — Has larger flowers and is of better growth than Othello Spencer.

NUBIAN

Originated by House. *Introduced by* House, 1911.

Donated by Burpee, 1913.

Description in brief — A deep maroon self.

Description in detail — Color of standard between purple-brown 166 and deep carmine-violet 174 (4 or darker); wings deep carmine-violet 174 (2–3). Flower large, waved form; standard large, slightly waved; wings short and broad. Flowers three, equidistant, close, on long, strong stems. Moderate fragrance. Bloom profuse. Sunproof. A garden, market, or exhibition variety. Plant of tall, slender growth. Leaflets broad, round, dark green.

Synonyms — King Manoel is practically the same.

Remarks — The best of this color group. Stock pure, true.

OTHELLO SPENCER

Originated by Morse. *Introduced by* Burpee, Morse, 1909.

Donated by Burpee, Morse, 1910.

Description in brief — A very large, very waved, maroon variety, excellent for garden or exhibition use.

Description in detail — Color of standard plum-violet 172 (4); wings deep purple 185 (1–2); flower has almost black veins. Standard very large, decidedly and uniformly waved; wings waved, very long and broad. Flowers three, on long, strong stems. Fragrance slight or none. Bloom profuse, continuous. Plant of tall, strong growth. Seed large, round, few in number.

Comparison — Long the standard maroon waved variety, but now surpassed by Nubian and King Manoel.
Remarks — Both stocks fixed.

PRINCE OF ASTURIAS

Originated by Breadmore. *Introduced by* Breadmore, 1908.
Donated by Rawson, 1910.
Description in brief — A large, waved, maroon, garden variety.
Description in detail — Color of standard plum-violet 172 (4); wings 172 (2–3). Standard large, waved; wings large, hooded, concealing the keel. Flowers two to three, on fair stems. Fragrant. Bloom free. Plant of moderately vigorous growth.
Comparison — Inferior to Othello Spencer.
Remarks — Stock mixed.

SILAS COLE

Originated by Cole. *Introduced by* Cole, 1910.
Donated by Cole, 1910.
Description in brief — A large, deep maroon, waved variety.
Description in detail — Color of standard rich pansy-violet 191 (3–4); wings deep purple 185 (1). Standard medium to large, generally not waved; wings long and narrow, concealing the keel. Flowers two to four, on long stems. Bloom profuse. Plant of moderately tall, healthy growth. Calyx and pedicel blue-black.
Comparison — Resembles Black Knight in color.
Remarks — Contained one rogue. Did not attain to Spencer size or form.

VICTOR UNWIN

Originated by Unwin. *Introduced by* Unwin, 1913.
Donated by Unwin, 1913.
Description in brief —" Rich deep chocolate or mahogany colored self, free from any trait of purple."— Unwin's catalogue.
Description in detail — Color of standard plum-violet 172 (3–4), tinged with violet; wings deep carmine-violet 174 (3–4). Flower large, waved form; standard large, waved; wings short and broad, concealing the keel. Flowers two to three, on short stems. Moderately fragrant. Moderately productive. Sunproof. Plant of medium height and slender, healthy growth. Leaflets broad, pointed, dark green.

Maroon-Purple

ARTHUR GREEN

Originated by Dobbie. *Introduced by* Dobbie, 1911.
Donated by Boddington, 1911; Burpee, Dobbie, Morse, 1912; Burpee, 1913.
Description in brief — Standard carmine-violet; wings deep purple.
Description in detail — Color of standard deep carmine-violet 174 (3–4), veined darker; wings deep purple 185 (2–3), sometimes with slight tints and markings of violet-purple. Flower very large, waved form; standard very large, waved; wings long and broad, spreading but drooping. Flowers three to four, irregular on strong stems of medium length. Fragrance moderate. Moderately productive. Plant of tall, strong growth. Leaflets broad, pointed, dark green; tendrils green.

Othello Spencer

Tennant Spencer

CAPTAIN OF THE BLUES SPENCER

Originated by Morse. *Introduced by* Morse, 1909.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — A very large, waved variety, with bright purple standard and blue wings. Excellent for garden or exhibition.

Description in detail — Color of standard reddish violet 180 (4); wings bishop's violet 189 (3). Standard very large, much waved; wings large, waved, long and broad. Flowers two to four, on long, strong stems. Fragrant. Bloom profuse, continuous, lasts well on the plants. Sunproof. Plant of tall, stout, healthy growth.

Remarks — Not fixed. Not correctly named, since it does not resemble Captain of the Blues in color. One of the largest-flowered varieties.

JOHN RIDD

Originated by Stark. *Introduced by* Stark, 1912.

Donated by Stark, 1912; Boddington, 1913.

Description in brief — "A large, waved, purple self."— Sweet Peas Up to Date.

Description in detail — Color of standard plum-violet 172 (4); wings vinous-mauve 184 (4). Flower large, waved form; standard large, waved, slightly auriculate; wings large, long and broad, spreading. Substance good. Flowers three to four, on long, strong stems. Very fragrant. Bloom scant to medium. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Remarks — Stock pure, true.

MAROON PARADISE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1909.

Donated by Miss Hemus, 1910.

Description in brief — " Deep maroon, waved."— Sweet Pea Annual.

Description in detail — Color of standard deep purple 185 (2–3); wings bishop's violet 189 (2–3); reverse bright violet-purple 190 (4). Flower large, waved form; standard large, Spencer-waved; wings long and broad, spreading. Flowers three, equidistant on long stems. Bloom profuse. Sunproof. Plant of medium height and stout, healthy growth. Leaflets narrow, pointed; color in axils of leaves and leaflets; tendrils colored.

Comparison — At this station in 1910 this variety was distinct from Black Knight.

MRS. E. COWDY

Originated by Bolton. *Introduced by* Bolton, 1913.

Donated by Boddington, 1913.

Description in detail — Color of standard plum-violet 172 (3–4); wings deep purple 185 (2–3), veined with plum-violet. Flower large, waved form; standard large, waved; wings short and broad, concealing the keel. Flowers three, equidistant, close, on medium stems. No fragrance. Moderately productive. Sunproof. Plant of tall, slender growth. Leaflets broad, pointed, dark green.

Comparison — Similar to John Ridd, perhaps a less deep purple.

Remarks — Stock pure, true.

PURPLE PRINCE SPENCER

Originated by Dickson. *Introduced by* Burpee, 1911.

Donated by Burpee, 1911.

Description in brief — " Standard purplish maroon, wings rosy purple."— Sweet Peas Up to Date.

Description in detail — Color of standard deep purple 185 (3); wings bishop's violet 189 (4). Flower very large, waved form; standard large, waved; wings large, long and broad. Flowers borne on long, strong stems. Plant of tall, strong, vigorous growth.

Comparison — This is almost a self and therefore differs from Captain of the Blues Spencer. In this respect it is an improvement.

Remarks — This is not the color of the old variety Purple Prince.

WAVERLY SPENCER

Originated by Morse. *Introduced by* Morse, 1909.

Donated by Burpee, 1911.

Description in brief —" Purplish maroon, wings rosy purple."— Sweet Peas Up to Date.

Comparison — Similar to Captain of the Blues Spencer, but smaller.

Remarks — Only one plant appeared to resemble the old Waverly in color.

Maroon-Red

BRUNETTE

Originated by Dobbie. *Introduced by* Dobbie, 1913

Donated by Dobbie, 1913.

Description in brief — A large, waved, rich deep mahogany self.

Description in detail — Color of standard and wings plum-violet 172 (4 or darker). Flower large, waved form; standard large, much waved; wings large, concealing the keel. Flowers two to three, on medium stems of short length. No fragrance. Bloom profuse. Burns slightly. Plant of medium height and slender growth. Leaflets narrow, pointed, dark green; tendrils green.

Remarks — An excellent variety. Stock pure, true.

RED CHIEF

Originated by Bolton. *Introduced by* Bolton, 1910.

Donated by Sydenham, 1913.

Description in detail — Color of standard plum-violet 172 (4 or darker); wings plum-violet 172 (1–2). Flower large, waved form; standard large, waved; wings long and broad, concealing the keel. Flowers three, on strong stems of medium length. Moderately fragrant. Moderately productive. Sunproof. Plant of tall, slender growth. Leaflets broad, round, dark green.

Remarks — With Brunette the leader of its class.

Mauve

A. J. COOK

Originated by Unwin. *Introduced by* Unwin, and Watkins & Simpson, 1907.

Donated by Rawson, Unwin, and Watkins & Simpson, 1910.

Description in brief — A moderately large, violet-mauve variety, of Unwin form.

Description in detail — Standard opens violet-mauve 195 (1), changing to 195 (4); wings tinted with more violet, which becomes deeper, toward bright violet-purple 190 (1). Standard medium to large, Unwin type; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Fragrant. Bloom profuse, continuous. A garden or market variety. Plant of medium height and stout, healthy growth. Seed small, mottled.
Remarks —A distinct and worthy variety. One stock pure; rogues mostly Othello.

AMETHYST

Originated by Aldersey. *Introduced by* Aldersey, 1911.
Donated by Aldersey, 1912.
Description in detail — Color of standard pure mauve 181 (3–4), shading to bright violet at base; wings bright violet 198 (1), sometimes with a rosy tinge. Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Moderate fragrance. Moderately productive. Plant of tall, slender growth. Leaflets broad, pointed; tendrils green.
Comparison — Similar to Royalty.

BERTHA MASSEY

Originated by Bide. *Introduced by* Bide, 1912.
Donated by Boddington, 1912, 1913.
Description in brief — A large, waved, lilac-mauve variety.
Description in detail — Color of standard pure mauve 181 (1–2); wings bright violet 198 (1–2), edged with purplish mauve. Flower large, waved form; standard large, slightly waved; wings long and broad, concealing the keel. Flowers three, equidistant, close, on medium stems. Moderate fragrance. Productive. Sunproof. Plant of medium height and slender growth.
Comparison — Surpassed by Frances Deal.
Remarks — Stock pure in 1912, mixed in 1913.

BETTY

Originated by Dobbie. *Introduced by* Dobbie, 1912.
Donated by Dobbie, 1912.
Description in brief — A purplish mauve variety.
Description in detail — Color of standard pure mauve 181 (1), shading often to purplish mauve 186 (1); wings purplish mauve. Flower very large, waved form; standard very large, much waved, slightly auriculate; wings very large, long and broad. Flowers three, equidistant on long stems of medium strength. Moderately fragrant. Bloom moderate. Sunproof. Plants of tall, slender, healthy growth. Leaflets broad, pointed; tendrils colored.
Comparison — Has paler and larger flowers than Tennant Spencer.

EMILY ECKFORD SPENCER

Originated by ————. *Introduced by* Burpee, 1911.
Donated by Burpee, for advance trial, 1910.
Description in brief — A large, mauve, Spencer variety.
Description in detail — Standard opens bluish lilac 183 (1), changing to bright violet 198 (1); wings heliotrope 188 (3), changing to bright violet 198 (2). Standard large, slightly waved; wings partly open, long and broad. Flowers two to three.

Fragrant. Bloom profuse. A garden, market, or exhibition variety. Plant of medium height and stout, healthy growth. Color in axils of leaves. Seed mottled.

Comparison — Distinct in color from The Marquis.

Remarks — A fixed stock.

EMPRESS

Originated by Deal. *Introduced by* Deal, 1911.

Donated by Deal, 1912.

Description in brief — A rich purple-mauve.

Description in detail — Color of standard reddish violet 180 (1); wings deep purple 185 (1). Flower very large, waved form; standard very large, waved, sometimes double; wings very large, long and broad, spreading. Flowers two to three, on medium stems. Very fragrant. Productive. Sunproof. Plant of tall, strong growth. Leaflets broad.

Comparison — Has less red in standard, but otherwise is similar to Annabel Lee.

Remarks — Color rogues: (1) pure cream, (2) pale rosy pink.

FRANCES DEAL

Originated by Deal. *Introduced by* Deal, 1912.

Donated by Deal, 1912.

Description in brief — "A rosy heliotrope."— Sweet Peas Up to Date.

Description in detail — Color of standard and wings reddish violet 180 (1), with a light spot at base of standard. Flower very large, waved form; standard very large, much waved; wings large, long and broad, spreading. Flowers two to three, irregularly placed, usually far apart, on long, strong stems. Moderate fragrance. Bloom profuse. Sunproof. Plant of tall, strong, healthy growth. Leaflets broad, pointed; tendrils colored.

Comparison — Superior to Bertha Massey.

HELIO PARADISE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — Large, pale rosy heliotrope, waved.

Description in detail—Color of standard purplish mauve 186 (1–2), deepest at base; wings bishop's violet 189 (2). Standard large, Spencer-waved; wings large, waved, long and broad. Flowers two to three, on long, strong stems. Moderately fragrant. Bloom profuse. Sunproof. Plant of medium height and moderately strong growth. Tendrils colored; color in axils of leaves. Seed mottled.

Comparison — Similar to The Marquis, but not superior.

Remarks — A fixed stock.

HELIOTROPE SPENCER

Originated by ——————. *Introduced by* Henderson, 1910.

Donated by Henderson, 1910.

Description in brief — Large, hooded, deep purple-mauve.

Description in detail — Color of standard bishop's violet 189 (1–2); wings 189 (1–3). Standard large, hooded; wings large, long and broad, concealing the keel. Flowers

two, on long, strong stems. Very fragrant. Bloom profuse, continuous. Plant of medium height and strong, healthy growth. Color in axils of leaves. Seed mottled, large.

Comparison — Color similar to Mrs. Walter Wright.

Remarks — A pure stock. Flowers did not take Spencer form.

MAUVE PARADISE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — A medium-sized, mauve variety.

Description in detail — Color of standard bluish lilac 183 (1); wings 183 (1–2). Standard of medium size; wings large, long and narrow, spreading. Flowers two to three. Moderate fragrance. Bloom medium. Burns slightly. Plant of medium height and stout, healthy growth. Seed mottled.

Comparison — Wings always paler than those of The Marquis or Tennant Spencer.

Remarks — Introducer stated that the stock might give some Primrose Paradise sports. This occurred in the tests at this station.

MAUVE QUEEN

Originated by Dobbie. *Introduced by* Dobbie, 1912.

Donated by Dobbie, 1912.

Description in brief — A large, waved, mauve variety.

Description in detail — Color of standard purplish mauve 186 (1), shading toward violet-mauve 195 (1) in center; wings violet-mauve 195 (1). Flower very large, waved form; standard very large, slightly waved, with slightly auriculate base; wings very large, long and broad. Substance good. Flowers three, equidistant on medium stems. Very fragrant. Bloom profuse. Sunproof. Plant of medium height and slender, healthy growth. Leaflets broad, pointed; tendrils green.

Comparison — Similar to Winsome, but a trifle more purple.

MRS. HESLINGTON

Originated by W. S. Heslington. *Introduced by* Dobbie, 1912.

Donated by Dobbie.

Description in detail — Color of standard purplish mauve 186 (1–2), shading to bright violet 198 (1–2) in the center; wings bright violet 198 (1–2). Flower very large, waved form; standard very large, often double, much waved, with auriculate base; wings long and broad. Substance good. Flowers three, equidistant on long stems of medium strength. Moderate fragrance. Bloom profuse. Sunproof. Plant of tall, slender, healthy growth. Leaflets broad, pointed; tendrils green.

Comparison — Very similar to Mauve Queen, but differs in form of flower and in color of wings. More mauve than Florence Nightingale.

ROYALTY

Originated by Bath. *Introduced by* ————.

Donated by Bath, 1912.

Description in detail — Color of standard reddish violet 180 (1); wings bright violet-purple 190 (1). Flower of medium size, waved form; standard of medium size,

slightly waved; wings of medium size, drooping. Flowers three, on medium stems. Moderate fragrance. Bloom profuse.

Comparison — Much like Dobbie's Violet Flush.

Remarks — Of no special merit at this station.

TENNANT SPENCER

Originated by Morse. *Introduced by* Morse, 1909.

Donated by Morse, 1910; Burpee, 1911.

Description in brief — Large, waved, purple-mauve self.

Description in detail — Color of standard purplish mauve 196 (2–3); wings 186 (1–2) on the inside, 186 (2–3) on the outside. Standard large, waved; wings waved, long and broad, concealing the keel. Flowers two to four, often four, on strong stems of medium length. Very fragrant. Bloom profuse, continuous. Plant of medium height and moderately strong growth. Tendrils colored; color in axils of leaves. Seed mottled.

THE MARQUIS

Originated by Dobbie. *Introduced by* Dobbie, 1908.

Donated by Dobbie, 1910.

Description in brief — A large, purplish mauve, waved variety.

Description in detail — Color of standard purplish mauve 186 (4); wings bishop's violet 189 (4); the standard showing more red and the wings more blue. Standard large, waved; wings very large, waved, long and broad, concealing the keel. Flowers two to three, on long, strong stems. Fragrant. Bloom profuse. A garden, market, or exhibition flower. Plant of medium height and moderately strong growth. Seed mottled, wrinkled.

Remarks — The 1910 stock was mixed and contained one Gladys Unwin.

Orange-Pink

CARENE

Originated by ————. *Introduced by* Watkins & Simpson, 1912.

Donated by Boddington, 1912, 1913.

Description in brief — A large, deep orange-pink variety.

Description in detail — Color of standard salmon-pink 126 (3–4), veined slightly darker; wings 126 (4), shading into purple-rose 150 (3–4) at base. Flower very large, waved form; standard very large, waved; wings very large, long and broad, open. Flowers two to three, equidistant on long, strong stems. Very fragrant. Bloom profuse. Plant of tall, slender growth. Leaflets broad, pointed; tendrils green.

Comparison — Is of stronger growth, has better flower stems and slightly larger flowers with more red in the wings, and exhibits less burning, than Stirling Stent.

EDITH TAYLOR

Originated by Holmes. *Introduced by* Holmes, Sydenham, 1912.

Donated by Sydenham, 1912, 1913.

Description in brief — " A waved salmon-rose self."— Sweet Peas Up to Date.

Description in detail — Color of standard and wings cerise 123 (1–2); standard veined darker. Flower very large, waved form; standard slightly waved, very large;

wings large, long and broad, spreading. Flowers three, on long, stout stems. Fragrance almost none. Burns slightly. Wet weather injures slightly. Plant of medium height and slender growth. Leaflets broad, pointed.

Comparison — A little less orange than Helen Lewis.

EDROM BEAUTY

Originated by Malcolm. *Introduced by* Dobbie, 1911.

Donated by Dobbie, 1912, 1913.

Description in brief — Standard orange, wings rosy salmon.

Description in detail — Color of standard salmon-pink 126 (2), with darker veins; wings purple-rose 150 (2). Flower very large, waved form; standard very large, Spencer-waved, sometimes double; wings large, long and broad. Flowers on long, strong stems. Bloom moderately productive, does not last well on the plant. Burns badly. Suffers slightly in wet weather. Plant of tall, strong growth. Leaflets broad, round; tendrils green.

GLYN TURQUAND

Originated by Alsen. *Introduced by* ———.

Donated by Alsen, 1912.

Description in brief — Rich crimson-scarlet, with a suggestion of orange.

Description in detail — Color of standard and wings carmine-lake 121 (1–2), veined slightly darker. Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Flowers three, on strong, very long stems. No fragrance. Moderately productive. Burns slightly. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green; foliage rich dark green.

Comparison — An improved Helen Lewis.

HELEN GROSVENOR

Originated by Aldersey. *Introduced by* Aldersey, 1910.

Donated by Sydenham, 1912.

Description in brief — A deep orange-salmon.

Description in detail — Color of standard madder lake 122 (1–2), shading to deep rose-pink at the base; wings deep rose-pink 120 (2–3), delicately veined with darker color. Flower large, waved form; standard large, slightly waved, sometimes double; wings long and broad, spreading. Flowers two to four, irregularly arranged on long, strong stems. Moderately fragrant. Moderately productive. Burns slightly. Is somewhat injured by wet weather. Plant of tall, strong growth.

Comparison — Closely resembles Helen Lewis. Possibly a deeper color.

HELEN LEWIS

Originated by J. Watson. *Introduced by* Breadmore, 1905.

Donated by Boddington, Dobbie, Morse, Unwin, 1910.

Description in brief — Large, waved, rosy scarlet and cerise. Popularly known as orange. Suitable for all purposes.

Description in detail — Color of standard bright rosy scarlet 124 (2–3); wings deep cerise 123 (1). Standard large, Spencer-waved; wings large, waved, long and broad, concealing the keel. Flowers two to four, on long, strong stems. Moderately fragrant. Plant of medium, stout, healthy growth. Seed black, large, round.

Synonyms — Orange Countess (Sydenham, 1905) and Mrs. Sydenham (Burpee, 1905).
Remarks — Of the four stocks received in 1910, two exhibited rogues.

LAURA WYATT

Originated by Dipnall. *Introduced by* Dipnall, 1913.

Donated by Dipnall, 1912.

Description in detail — Color of standard salmon-pink 74 (1), with carmine veining; wings carmine-lake 121 (1–2). Flower large, waved form; standard large, slightly waved, sometimes double; wings long and narrow, spreading. Flowers two to three, on medium stems. Fragrance little or none. Moderately productive. Burns badly. Plant of tall, strong growth.

LORD ALTHORP

Originated by Cole. *Introduced by* Cole, 1910.

Donated by Cole, 1910.

Description in brief — Large, waved, orange-pink.

Description in detail — Color of standard bright rosy scarlet 124 (2–3); wings deep cerise 123 (3–4).

Comparison — A fine strain of Helen Lewis, but does not stand the sun so well.

Remarks — A pure stock.

ORANGE SPENCER

Originated by ——————. *Introduced by* Henderson, 1910.

Donated by Henderson, 1910.

Description in brief — A large, orange, Spencer variety.

Description in detail — Color of standard rosy scarlet 124 (2–3); wings cerise 123 (2–3).

Comparison — Similar in color to Miss Wilmott Improved.

Remarks — A pure stock.

PHOEBUS

Originated by Bide. *Introduced by* Bide.

Donated by Bide.

Description in detail — Color of standard Lincoln red 88 (1), veined darker; wings geranium red 111 (lighter than 1). Flower large, waved form; standard large, much waved, with broad base; wings large, long and broad, spreading. Flowers three, on slender stems of medium length. Moderate fragrance. Bloom profuse. Plant of medium height and slender growth. Leaflets broad, pointed; tendrils green.

PRINCE OF ORANGE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — Originator describes this as a large, waved, very vigorous, orange variety.

Remarks — Very unfixed. Was one half Countess Spencer, or Paradise, and one half John Ingman. No orange in it. The later selection has not been tested at this station.

Helen Lewis *Arthur Unwin*

Elsie Herbert *Evelyn Hemus*

Orange-Scarlet

ANDREW AITKEN

Introduced by Bolton, 1913.

Originated by Bolton.
Donated by Boddington, 1913.
Description in brief — " A soft salmon-colored variety."— Bolton's catalogue.
Description in detail — Color of standard salmon-pink 126 (2–3), flushed with Rose Neyron red at base; wings rosy pink 118 (2–3), flushed with Rose Neyron red. Flower large, waved form; standard large, waved; wings large, long and broad, concealing the keel. Flowers three, equidistant, close, on medium stems. Moderately fragrant. Moderately productive. Burns slightly. Plant of medium height and slender growth. Leaflets broad, round, dark green.
Remarks — Stock pure, true.

ANGLIAN ORANGE

Introduced by King, 1911.

Originated by King.
Donated by King, 1913.
Description in brief — A large, waved, salmon-pink variety.
Description in detail — Color of standard bright rosy scarlet 124 (1), tinged with purple-rose on the edge and at the base; wings purple-rose 150 (1 or lighter). Flower large, waved form; standard large, slightly waved; wings large, concealing the keel. Flowers three, equidistant, close, on medium stems. No fragrance. Bloom profuse. Burns somewhat. Plant of medium height and strong growth. Leaflets broad, round, dark green.
Remarks — Contained two color rogues.

DAZZLER

Introduced by Breadmore, 1910.

Originated by Breadmore.
Donated by Farquhar.
Description in brief — " Bright flame color."— Sweet Pea Annual.
Description in detail — Color of standard and wings salmon-pink 126 (2–3). Flower large, waved form; standard large, slightly waved; wings short and broad, concealing the keel. Flowers three, on medium stems. No fragrance. Bloom medium. Burns slightly. Plant of tall, slender growth. Leaflets broad, round, dark green.
Comparison — Similar to Andrew Aitken.
Remarks — Stock pure, true.

EDNA UNWIN IMPROVED

Introduced by Unwin, 1910.

Originated by Unwin.
Donated by Unwin, 1910.
Description in brief — A medium-sized, slightly waved variety.
Description in detail — Color of standard rosy scarlet 124 (4); wings cerise 123 (2–3). Standard medium to large, slightly waved; wings moderately long and broad, partly open. Flowers two to three, on strong stems of moderate length. Fragrance slight. Bloom free. Burns slightly. Plant of tall, stout, healthy growth. Seed dark brown.
Comparison — Similar to St. George, but slightly superior in form.
Remarks — A pure stock.

ORANGE KING

Originated by Bide. *Introduced by* Bide, 1911.

Donated by Bide, 1910.

Description in brief — This variety is said to be a true orange self.

Comparison — The orange-colored flowers were similar to Edna Unwin Improved or St. George.

Remarks — A very unfixed stock. One plant Henry Eckford. Mostly pink-flowered plants.

ORANGE PERFECTION

Originated by Box. *Introduced by* Box, 1912.

Donated by Box, 1912.

Description in brief — Standard orange, wings rose.

Description in detail — Color of standard shrimp pink 75 (1); wings deep rose-pink 120 (1–2). Flower large, waved form; standard large, slightly waved; wings large, long and broad, spreading. Flowers two to three, on slender stems of medium length. No fragrance. Bloom scant. Burns slightly. Plant of medium, very slender growth. Leaflets broad, pointed.

Comparison — Smaller, of paler color and poorer bloom, and a weaker plant than Thomas Stevenson in the trials at this station in 1912.

RUBY

Originated by ——————. *Introduced by* Aldersey, 1910.

Donated by Aldersey, Marsden Jones.

Description in brief — " Standard bright orange scarlet; wings deep rose."— Introducer's description.

Description in detail — Color of standard coral-red 76 (1–2), veined darker; wings carthamus red 88 (1), sometimes veined darker. Flower medium to large, slightly waved form; standard medium large, slightly waved; wings long and broad, spreading. Flowers two to three, on rather weak, short stems. Fragrance very little or none. Burns badly. Is badly injured by wet weather. Plant of moderately tall, slender growth. Leaflets broad, pointed.

Comparison — Similar to Thomas Stevenson in color, but was the poorest of the orange group.

ST. GEORGE

Originated by ——————. *Introduced by* Hurst, 1908.

Donated by Boddington, Dobbie, 1910.

Description in brief — A medium-sized garden variety.

Description in detail — Color of standard bright rosy scarlet 124 (3–4); wings deep rose-pink 120 (2–3). Standard of medium size, some very slightly waved; wings moderately long and broad, concealing the keel. Flowers two to three, generally two, on short stems. Fragrance very slight. Bloom free. Burns badly. Plant of medium height and stout growth. Seed black, irregular in shape.

Comparison — Wings are not the same color as the standard, neither are they the color of the wings of Orange Spencer or Miss Wilmott Improved.

THOMAS STEVENSON

Originated by Holmes. *Introduced by* Sydenham, 1911.

Donated by Boddington, Burpee, Dobbie, Sydenham, 1912; Burpee, Dobbie, Sydenham, 1913.

Description in brief — A rich orange-scarlet.

Description in detail — Color of standard madder lake 122 (2–3), veined darker; wings carmine-lake 121 (2–3), veined darker. Flower very large, waved form; standard very large, slightly waved; wings large, long and broad, spreading. Flowers on long, strong stems. Moderately fragrant. Moderately productive. Burns slightly. Plant tall, stout. Leaflets broad, pointed; tendrils green.

Comparison — Plant is of stronger growth, and produces larger flowers on longer stems, than Stirling Stent.

Remarks — The leading variety in this group.

Picotee Edged (Cream ground)

EVELYN HEMUS

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1908.

Donated by Miss Hemus, 1910.

Description in brief — Large, waved, picotee-edged pink on a primrose ground, for garden, market, or exhibition use.

Description in detail — Color of standard picotee-edged pale rosy pink 129 (1), on a fleshy white 9 (3) ground; wings 9 (2–3). Standard large, Spencer-waved; wings waved, long and broad. Flowers two to four, on long, strong stems. Fragrant. Bloom profuse, continuous. Plant of medium height and stout, healthy growth.

Comparison.— Closely resembles Mrs. C. W. Breadmore.

Remarks — A pure stock.

HELEN WILLIAMS

Originated by Stark. *Introduced by* Stark, 1913.

Donated by Stark, 1912.

Description in brief — A large, waved, picotee variety.

Description in detail — Color yellowish white 13 (1), edged with purple rose 150 (1), deeper on back; wings yellowish white 13 (1). Flower very large, waved form, standard very large, much waved; wings large, long and broad. Flowers three to four, wide apart on very long, strong stems. Moderately fragrant. Bloom medium. Plant of strong, vigorous growth. Foliage dark green; color in axils of peduncles and leaflets.

Comparison — Better than Mrs. Breadmore in 1912. Not tested in 1913.

MRS. C. W. BREADMORE

Originated by Breadmore. *Introduced by* Breadmore, 1908.

Donated by Boddington, Stark, Dobbie, 1910; Burpee, 1911; Rohnert, 1912.

Description in brief — Large, waved, picotee-edged pink on a primrose ground.

Description in detail — Color of standard picotee-edged pale lilac-rose 130 (1), on an amber-white 12 (1) ground; wings 12 (1). Standard large, Spencer-waved; wings

waved, long and broad. Flowers two to three, on long, strong stems. Fragrant. Bloom profuse, continuous. Sunproof. Plant of medium height and stout, healthy growth.

Comparison — Closely resembles Evelyn Hemus.

Remarks — A pure stock.

Picotee Edged (White ground)

CHASTITY

Originated by Bath. *Introduced by* Bath, 1912.

Donated by Bath.

Description in brief — Large, waved, pure white, with a blush edge.

Description in detail — Color of standard on opening shows faint primrose, later tinted violet-rose 154 (1); wings similar, but becoming a deeper tint. Flower very large, waved form; standard very large, slightly waved, many doubles; wings large, long and broad, drooping. Substance good. Flowers three, irregularly spaced on long, strong stems. Moderately fragrant. Productive. Plant of very tall, strong growth. Leaflets long, broad; tendrils colored.

DAINTY SPENCER

Originated by ——————. *Introduced by* Burpee, 1911.

Donated by Burpee, for advance trial, 1910.

Description in brief — Large, waved, picotee-edged pink on a white ground.

Description in detail — Color of flower rosy white 8 (2) ground, with edge of standard Rose Neyron red 119 (1); edge of wings 119 (2). Standard large, very slightly waved; wings waved, long and broad, concealing the keel. Flowers two to four, on long, strong stems. Fragrant. Bloom medium. Plant of medium height and stout, healthy growth.

Comparison — Not so large as Elsie Herbert, but otherwise similar to it.

DISTINCTION

Originated by Bath. *Introduced by* Bath, 1910.

Donated by Bath, 1910.

Description in brief — Large, waved, picotee-edged pink on a white ground.

Comparison — Very similar to Elsie Herbert.

Remarks — Not a fixed stock.

ELSIE HERBERT

Originated by Breadmore. *Introduced by* Breadmore, 1908.

Donated by Dobbie, Miss Hemus, Unwin, 1910; Burpee, 1911; Morse, 1912.

Description in brief — Large, waved, picotee-edged pink on a white ground. A garden, market, or exhibition variety.

Description in detail — Color of standard lilacy white 7 (2–3), with a picotee edge of purple-rose 150 (1); wings 7 (1), with pale lilac-rose 130 (4) edge. Standard large, Spencer-waved; wings large, partly open, waved. Flowers two to four, on long, strong stems. Fragrant. Bloom profuse, continuous. Plant of tall, stout, healthy growth. Seed black.

Remarks — Pure stocks. A distinct variety. The standard variety of this color.

ERIC HARVEY

Originated by Unwin. *Introduced by* Unwin, 1911.

Donated by Unwin, for advance trial, 1910.

Description in brief —A large, beautifully waved flower, useful for decoration and exhibition.

Description in detail — Color of bud buff; opening flower shows trace of buff; standard suffused with mauve-rose, deepest at the edges, and deeper still on the back; wings flushed lilacy white 7 (4). Standard large, waved; wings large, varying from hooded to waved, concealing the keel. Flowers three, on long, strong stems. Plant grows to medium height, strong and healthy.

Comparison — Distinct from Martha Washington.

Remarks — Contained John Ingman rogue.

MARTHA WASHINGTON

Originated by Routzahn. *Introduced by* Henderson, 1910.

Donated by Henderson, 1910, 1911.

Description in brief —A very large, waved variety, with a heavy picotee edge on a pure white ground.

Description in detail — Color of standard white from base to center, shading to a pink edge; as the flower ages the suffusion increases; wings picotee-edged pink. Standard large, Spencer-waved; wings long and broad, waved.

Comparison — Distinct from Elsie Herbert.

Remarks — The 1910 stock produced one plant of Othello, but the variety is usually reported true. The 1911 stock was true.

PICOTEE

Originated by ———————. *Introduced by* Watkins & Simpson, 1910.

Donated by Watkins & Simpson, 1910; Boddington, 1911; Rohnert, 1912.

Description in brief — A waved, picotee-edged carmine variety.

Description in detail — Color of standard faintest blush, edged with purple-rose 150 (1–3); wings edged with pale pink. Flower very large, waved form; standard very large, much waved; wings long and broad, spreading, often drooping. Very fragrant. Bloom profuse. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Comparison — Similar to Elsie Herbert and Distinction.

WINIFRED DEAL

Originated by Deal. *Introduced by* Deal, 1910.

Donated by Deal, 1910, 1912.

Description in brief — Large, waved, picotee-edged pink on a white ground.

Comparison — Similar to Elsie Herbert.

Remarks — Not a true stock. The 1912 stock was true.

Pink

AUDRY CRIER

Originated by Breadmore. *Introduced by* Breadmore, 1908.

Donated by Rawson, 1910.

Description in brief — Described as salmon-pink.

Remarks — One of the varieties that it has been impossible to fix. This stock was almost entirely Helen Lewis, with one plant Prince Olaf, two Menie Christie, and several White Spencer.

BEATRICE SPENCER

Originated by Morse. *Introduced by* Morse, 1909.

Donated by Boddington, Morse, 1910; Burpee, 1911.

Description in brief— Catalogued as white, tinted soft pink and buff; wings have bright pink blotch at base.

Description in detail — Color of standard mauve-rose 153 (2); wings violet-rose 154 (1). Flower large; standard large, Spencer-waved; wings long and broad, waved. Flowers three, on strong stems of fair length. Bloom profuse, continuous. Plant of strong, healthy growth. Tendrils colored. Seed large, black.

BLUSH ROSE SPENCER

Originated by ————. *Introduced by* Henderson, 1910.

Donated by Henderson, 1910.

Description in brief — A large, rose-pink, waved variety.

Description in detail — Color of standard purple-rose 150 (1–2); wings mauve-rose 153 (1). Standard and wings large and waved.

Remarks — A badly mixed lot of plants containing mostly carmine-rose flowers, with Countess Spencer and White Spencer.

COUNTESS SPENCER

Originated by Cole. *Introduced by* Sydenham, 1904.

Donated by Boddington, Cole, Dobbie, Henderson, Morse, Rawson, 1910.

Description in brief — A large, rose-pink, waved variety, suitable for garden, market, and exhibition use.

Description in detail — Color of standard mauve-rose 153 (2–3); wings violet-rose 154 (1–2); color deeper in cool weather; color often deeper at the edges. Standard very large, waved; wings waved, long and broad. Flowers three to four, on long, very strong stems. Fragrant. Bloom profuse, continuous. Plant of strong, vigorous growth. Seed black.

Remarks — One stock pure. The forerunner of the waved, or Spencer, type.

ENCHANTRESS

Originated by Stark. *Introduced by* Stark, 1906.

Donated by Boddington, Stark, 1910.

Synonyms — Identical with Countess Spencer.

Remarks — Neither stock pure.

FLORENCE SPENCER

Originated by Cole. *Introduced by* Cole, 1907.

Donated by Rawson, 1910.

Description in detail — Color of standard violet-rose 154 (2–3); wings 154 (1–2). Flower of medium size, waved; standard of medium size, slightly waved; wings long and narrow. Flowers two to three, on long, slender stems. Productive. Plant of tall, strong growth. Leaflets broad, dark green.

Comparison — A trifle lighter in color than Countess Spencer.

Remarks — Not pure: contains Helen Lewis and E. J. Castle.

GLADYS UNWIN

Originated by Unwin. *Introduced by* Unwin, and Watkins & Simpson, 1905.

Donated by Boddington, Rawson, and Watkins & Simpson, 1910.

Description in brief — A rose-pink variety, of Unwin form; for garden or market use.

Description in detail — Color of standard mauve-rose 153 (1); wings violet-rose 154 (1). Flower large, standard moderately large, slightly waved; wings long and broad, hooded. Flowers two to three, on long stems. Productive. Produces a good crop of seed.

Comparison — Paler than Countess Spencer in cool weather. Standard more nearly upright and wings more incurved than those of Countess Spencer.

Remarks — Two stocks pure.

HERCULES

Originated by Stark. *Introduced by* Stark, 1911.

Donated by Stark, 1912; Boddington, 1913.

Description in brief — A very large, waved, pink self.

Description in detail — Color same as Countess Spencer. Flower very large, slightly waved form. Flowers three to four, on long, strong stems. Tendrils colored.

Comparison — A larger, but less waved, Countess Spencer. Better for exhibition than Countess Spencer.

LADY SARAH SPENCER

Originated by Cole. *Introduced by* Cole, 1910.

Donated by Cole, 1910.

Description in brief — Originator describes as pink suffused with salmon.

Synonyms — Same as Countess Spencer in all respects.

Remarks — Stock pure but not true.

LOVELY SPENCER

Originated by Morse. *Introduced by* Morse, 1909.

Donated by Morse, 1910.

Description in brief — Large, waved form of Lovely.

Description in detail — Color of standard pale lilac-rose 130 (2); wings 130 (3). Flower very large; standard large, Spencer-waved; wings large, long and very broad, waved, spreading. Flowers two to four, on long, strong stems. Bloom profuse, continuous. Plant of strong, healthy growth.

Comparison — Lighter in color than Countess Spencer.

Remarks — A distinct variety. A pure stock.

MARION

Originated by ——————. *Introduced by* Dobbie, 1911.

Donated by Dobbie, 1912.

Description in detail — Color of standard and wings violet-rose 154 (1–2). Flower large, waved form; standard large, broad, slightly waved; wings long and broad. Flowers three, equidistant on medium stems. Very fragrant. Moderately productive. Plant of medium height and slender, healthy growth. Leaflets broad, pointed; tendrils colored.

Remarks — Has been described as lilac-rose.

MRS. ALFRED WATKINS

Originated by Unwin. *Introduced by* Unwin, and Watkins & Simpson, 1907.

Donated by Boddington, Rawson, Unwin, and Watkins & Simpson, 1910.

Description in brief — Pale pink with lighter edges, Unwin type. A garden or market variety.

Description in detail — Color lilac-rose 130 (1–2), fading to almost white edges. Flower large, Unwin type; standard large, slightly waved; wings long and broad. Flowers three, on long stems. Productive. Burns more or less in the sun.

Comparison — Does not resemble Peach Blossom very closely.

Remarks — Three stocks pure. One stock contained one Captain of the Blues Spencer.

PARADISE

Originated by Miss Hemus. *Introduced by* Miss Hemus, Sydenham, 1907.

Donated by Boddington, Miss Hemus, Morse, Rawson, 1910.

Description in brief — A large, pink, waved variety.

Synonyms — Same as Countess Spencer.

Remarks — Miss Hemus' stock pure.

ZARA

Originated by Biffen. *Introduced by* Miss Hemus, 1908.

Donated by Miss Hemus, 1910.

Description in brief — A garden variety.

Description in detail — Color of standard hydrangea pink 132 (2–3); wings 132 (1–2). Flower large, Unwin form; standard large, slightly waved; wings medium, partly open. Substance good. Flowers two to four, on moderately long, strong stems. Fragrant. Bloom free. Plant healthy and of medium height.

Comparison — More buff than Lovely Spencer.

Synonyms — We should call it Honorable F. Bouverie Spencer.

Remarks — A pure stock.

Pink (Pale pink group)

CHARM

Originated by ——————. *Introduced by* Burpee, 1913.

Donated by Burpee, 1913.

Description in detail — Color of standard lilac-rose 178 (1 or paler). Flower large, waved form; standard large, slightly waved; wings short and broad, concealing the keel. Flowers three to four, irregularly placed on strong stems of medium length. Moderately fragrant. Moderately productive. Sunproof. Plant of medium height and slender growth. Leaflets dark green, broad, pointed; tendrils green.

ELFRIDA PEARSON

Originated by J. R. Pearson & Sons. *Introduced by* Pearson, 1911.

Donated by Dobbie, 1912; Burpee, 1913.

Description in brief — A large, waved, blush-pink variety.

Description in detail — Color lilac-rose 152 (1 to much lighter); flower opens with considerable primrose in the standard, which is blush-pink; flower changes, losing its

primrose tint, becoming a blush-pink on white. Flower large, waved form; standard large, waved, often double, sometimes triple. Plant of tall, strong, vigorous growth. Foliage dark green, healthy.

Comparison — Not so large as Princess Victoria, but more salmon. A deeper pink than Lady Evelyn Eyre.

Rose

EDNA TURNER

Originated by Dipnall. *Introduced by* Dipnall, 1911.

Donated by Dipnall.

Description in detail — Color of standard and wings purple-rose 150 (1). Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Moderately fragrant. Moderately productive. Burns slightly. Stems medium to long, slender. Plant of tall, strong growth. Leaflets broad.

Remarks — Two color rogues: (1) dark violet, (2) carmine-lake and orange.

KING MARJORIE

Donated by Dobbie, 1912.

Description in detail — Color of standard lilac-rose 152 (3–4), shading into Tyrian rose 155 (1–2); wings Tyrian rose 155 (1–2). Flower very large, waved form; standard very large, slightly waved; wings long and broad. Good substance. Flowers two to three, equidistant on long, strong stems. Fragrance none. Bloom scant. Sunproof. Plant of very tall, stout growth. Leaflets broad, pointed.

Comparison — An improved Marjorie Willis.

MARIE CORELLI

Originated by ————. *Introduced by* Burpee, Morse, 1910.

Donated by Burpee, Morse.

Description in brief — A waved "rose-carmine" variety.

Description in detail — Color of standard purple-rose 150 (3–4); wings purple-rose 150 (1–2). (See description of Marjorie Willis.)

Remarks — A pure stock.

MARJORIE WILLIS

Originated by Lumley. *Introduced by* Lumley, Breadmore, Wright, 1908.

Donated by Dobbie, 1910; Rohnert, 1912; Burpee, 1913.

Description in brief — A large, waved, rose and carmine variety, for garden and exhibition use.

Description in detail — Color of standard carmine-purple 150 (3); wings Tyrian rose 150 (1–2). Standard large, Spencer-waved; wings long and broad, concealing the keel. Flowers two to three, on long, strong stems. Very fragrant. Bloom profuse. Sunproof. Plant of medium height and stout, healthy growth. Tendrils colored; color in axils of leaves and leaflets.

Comparison — Very similar to Marie Corelli.

Remarks — A pure stock.

ROSABELLE

Originated by Malcolm. *Introduced by* Malcolm, 1912.
Donated by King, 1913.
Description in brief — A large, waved, rose variety.
Description in detail — Color of standard carmine-purple 156 (1), tinged with violet at the base; wings pure mauve 181 (1–2). Flower large, waved form; standard large, waved; wings short and broad, concealing the keel. Flowers three, on strong stems. Moderately fragrant. Bloom profuse. Burns slightly. Plant of tall, strong, vigorous growth. Leaflets broad, round, dark green.
Comparison — Superior to Marjorie Willis or Marie Corelli.

ROSE DIAMOND

Originated by Aldersey. *Introduced by* Aldersey, 1912.
Donated by Aldersey, 1912.
Description in brief — A large, waved, rose variety.
Description in detail — Color of standard carmine-lake 121 (2–3); wings carmine-lake 121 (1–2). Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Flowers three, irregularly placed on short, slender stems. Slightly fragrant. Moderately productive. Plant of medium height and slender growth. Leaflets narrow, pointed; tendrils colored.
Comparison — Lighter, purer rose shades than George Herbert.

Salmon Shades

BARBARA

Originated by Holmes. *Introduced by* Sydenham, Holmes, 1912.
Donated by Sydenham, 1912.
Description in brief — A salmon-orange self.
Description in detail — Color of standard shrimp pink 75 (2–3); wings madder lake 122 (1–2). Flower very large, waved form; standard very large, slightly waved; wings long and broad, spreading. Flowers two to three, on strong stems of medium length. Little, if any, fragrance. Moderately productive. Burns badly. Is badly injured by wet weather. Plant of medium height, strong. Leaflets broad, pointed; tendrils often colored.
Comparison — Flowers larger, bloom better, and stems stronger than Stirling Stent, but a lighter orange. A lighter orange than Thomas Stevenson.

EARL SPENCER

Originated by Cole. *Introduced by* Dobbie, Cole, 1910.
Donated by Boddington, 1911; Burpee, 1913.
Description in brief — A large, waved, orange variety.
Description in detail — Color of standard and wings salmon-pink 126 (1–2). Flower large, waved form; standard large, slightly waved; wings long and broad, concealing the keel. Flowers two to three, equidistant, close, on short to medium stems of medium strength. Not fragrant. Bloom profuse. Burns badly. Plant of medium height and strong growth. Leaflets broad, round, dark green.

INSPECTOR

Originated by Dobbie. *Introduced by* Dobbie, 1913.

Donated by Dobbie, 1913.

Description in brief — A duplex, or double, form of Stirling Stent.

Description in detail — (See Stirling Stent.)

Comparison — Is a strain of Stirling Stent producing a good percentage of doubles. If anything, it is of more vigorous growth than Stirling Stent.

Remarks — A very good duplex variety.

MELBA

Originated by Malcolm. *Introduced by* Dobbie, 1912.

Donated by Dobbie, 1912; Burpee, Dobbie, 1913.

Description in brief — An orange-salmon flower.

Description in detail — Color of standard salmon-carmine 125 (3–4), deepest on back; wings salmon-carmine 125 (1–2). Flower large, waved form; standard large, slightly waved, sometimes double; wings long and broad. Flowers two to three, on medium stems. Bloom profuse. Burns badly. Is badly injured by wet weather. Plant of medium height and strong growth. Leaflets broad, pointed; tendrils green.

Comparison — Is smaller and lighter, and has much more orange, than Helen Lewis. Burned less in 1913 trials than Earl Spencer.

STIRLING STENT

Originated by James Agate. *Introduced by* Agate, 1911.

Donated by Boddington, 1911; Burpee, 1912, 1913.

Description in brief — A bright salmon-orange variety.

Description in detail — Color of standard madder lake 122 (2–4), back 122 (4); wings madder lake 122 (1–2), back 122 (3–4). Flower large, waved form; standard large, slightly waved; wings short and broad, concealing the keel. Flowers two to three, on medium stems. Not fragrant. Bloom profuse. Burns slightly. Plant of medium height and stout growth. Leaflets broad, pointed, dark green.

Comparison — A deeper color, with much less burning, than Earl Spencer.

TORTOISE SHELL

Originated by Aldersey. *Introduced by* Aldersey, 1910.

Donated by Aldersey, 1912.

Description in brief — A shrimp pink variety.

Description in detail — Color of standard and wings shrimp pink 75 (2–3), veined darker. Flower of medium size, waved form; standard of medium size, slightly waved; wings long and broad, spreading. Flowers one to three, on medium stems. No fragrance. Bloom rather scant. Burns badly. Plant of medium height and slender growth.

Comparison — Color not so bright as Barbara.

Remarks — A pleasing, distinct color among new types.

Scarlet

BOLTON'S SCARLET

Originated by Bolton. *Introduced by* Bolton, 1913.

Donated by Boddington, 1913.

Description in brief — A large, waved, crimson variety.

Description in detail — Color of standard crimson-red 114 (1-2); wings amaranth-red 168 (1–2). Flower large, waved form; standard large, slightly waved; wings long and broad, concealing the keel. Flowers three, on medium stems. Moderate fragrance. Bloom medium. Burns slightly. Plant of tall, slender growth. Leaflets broad, round, dark green.

Remarks — Stock pure, true.

DOBBIE'S SCARLET

Originated by Dobbie. *Introduced by* Dobbie, 1913.

Donated by Dobbie, 1912, 1913.

Description in detail — Color of standard varies from crimson-red 114 (1) to carmine-red 116 (1); wings crimson-red 114 (1). Flower large, waved form; standard large, much waved, many double; wings long and broad, spreading. Flowers two to three, on long, strong stems. Fragrance moderate. Moderately productive. Sunproof. Plant of tall, strong growth. Leaflets broad.

Comparison — Similar to George Stark.

Remarks — In 1913 the best of the scarlets.

DORIS BURT

Originated by Unwin. *Introduced by* Unwin, 1910.

Donated by Unwin, 1910.

Description in brief — A large, scarlet, waved, garden variety.

Description in detail — Color of standard carmine-purple 156 (3). Wings long and broad, concealing the keel. Flowers three, on long stems. Very slight fragrance. Burns badly. Plant slender, of medium height. The foliage has a blue cast, the young shoots a purplish cast.

Remarks — A pure stock.

GEORGE STARK

Originated by Stark. *Introduced by* Stark, 1910.

Donated by Stark, 1910.

Description in brief — Medium to large, bright red.

Description in detail — Color of standard carmine-purple 156 (3–4); wings 156 (1). Standard medium to large, upright, open, flat or very slightly waved; wings long and broad, spreading. Flowers three, on long, strong stems. Mild fragrance. Bloom profuse. Plant of moderately strong growth. Calyx colored.

Remarks — Wings sometimes larger than standard. A pure stock as to color.

GEORGE STARK IMPROVED

Originated by Stark. *Introduced by* Stark, 1910.

Donated by Stark, 1910; Boddington, 1912.

Description in brief — A large, waved, scarlet variety suitable for all purposes.

Description in detail — Color of standard 156 (3–4); wings 156 (1). Standard large to very large. Spencer-waved, many double; wings long and broad, spreading. Flowers three, on long, strong stems. Very slight fragrance, if any. Bloom profuse. Burns in the sun. Growth strong and vigorous. Calyx colored.

Comparison — Color of Queen Alexandra.

Remarks — There is a double-flowered strain offered by Stark.

GEORGE WASHINGTON

Originated by ——————. *Introduced by* Henderson, 1910.

Donated by Henderson.

Description in brief — "A very large crimson scarlet."— Henderson's catalogue.

Remarks — This stock unfortunately produced two shades of red in equal proportion. Withdrawn after first season.

MISS E. F. DRAYSON

Originated by Unwin. *Introduced by* Unwin, 1908.

Donated by Unwin, 1910.

Description in brief — A medium-sized, scarlet, Unwin variety.

Description in detail — Color of standard carmine-purple 156 (3–4); wings, front 156 (1), back 156 (2). Standard of medium size, Unwin type; wings short and broad. Flowers two to three, on strong stems of moderate length. Burns slightly. Plant of short, slender growth. Seed round, black.

Comparison — Color between Coccinea and Queen Alexandra, but resembles the latter more closely.

Remarks — One maroon plant appeared in the stock.

PREMIER

Originated by Stark. *Introduced by* Stark, 1911.

Donated by Stark, 1912.

Description in detail — Color of standard crimson-red 114 (1–3), back a deeper color; wings crimson-red 114 (1). Flower very large, waved form; standard very large, waved slightly; wings short and broad. Flowers irregular on long, strong stems. Not fragrant. Moderately productive. Sunproof. Plant of medium height and strong growth. Leaflets broad.

Comparison — A similar flower to that of George Stark, but the plant is stronger.

RED PARADISE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — A medium-sized, waved, bright red variety.

Description in detail — Color of standard carmine-purple 156 (3–4); wings 156 (1–2). Standard of medium size, slightly waved; wings long and narrow. Flowers on strong stems of moderate length. Fragrance very slight. Sunproof. Plant not healthy. Growth stunted apparently from some physiological affection. Foliage blue-green.

Remarks — Stock mixed, two shades of red. Owing to the disease mentioned above, the variety did not show up so well as it probably should have done.

RED STAR

Originated by Malcolm. *Introduced by* Dobbie, 1912.

Donated by Dobbie, 1912, 1913.

Description in detail — Color of standard carmine-purple 156 (3–4); wings carmine-purple 156 (2–3). Flower large, open form; standard large, flat; wings long and broad. Moderately fragrant. Bloom scant. Burns slightly. Plant of tall, slender growth. Leaflets broad.

Comparison — Slightly better than George Stark.
Remarks — At this station this variety is the best of the Queen Alexandra color.

ROYAL SCARLET

Originated by Aldersey. *Introduced by* Aldersey, 1911.
Donated by Aldersey, 1912 (Aldersey's No. 139).
Description in brief — A large, waved, scarlet self.
Description in detail — Color geranium red 111 (1); wings the same color. Flowers large, waved form; standard large, slightly waved; wings long and broad, spreading. Flowers on short stems. No fragrance. Bloom scant. Burns slightly. Plant of medium height and slender growth. Leaflets broad, pointed.
Comparison — A duller and paler red than King Edward VII.

SCARLET EMPEROR

Originated by Holmes. *Introduced by* Holmes, Sydenham, 1912.
Donated by Sydenham, 1912, 1913.
Description in brief — A large, waved, crimson-scarlet self.
Description in detail — Color of standard and wings crimson-red 114 (1–2); wings lighter inside. Flower large, waved form; standard large, waved; wings short and broad, wide-spreading. Flowers two to three, equidistant on strong, medium to long stems. Moderately fragrant. Bloom profuse. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed.
Comparison — Is a better, clearer scarlet, blooms better, and burns less, than George Stark. Is a better scarlet and blooms better than Red Star.
Remarks — The best scarlet in 1912.

SCARLET EMPRESS

Originated by Holmes. *Introduced by* Holmes, Sydenham, 1912.
Donated by Sydenham, 1912, 1913.
Description in brief — A large, waved, scarlet variety.
Description in detail — Color of standard crimson-red 114 (1–2); wings the same color. Flower large, waved form; standard large, waved; wings short and broad, spreading. Flowers three, equidistant, close, on medium to long, strong stems. Moderately fragrant. Bloom profuse. Sunproof. Plant of medium height and stout growth.
Remarks — A good, bright, clear scarlet.

SCARLET MONARCH

Originated by Deal. *Introduced by* Deal, 1911.
Donated by Deal.
Description in brief — A crimson-scarlet self.
Description in detail — Color of standard currant red 115 (2–4); wings currant red 115 (1), veined darker. Flower large, waved form; standard large, waved slightly, with round, broad base; wings long and broad, spreading. Flowers two to three, on short stems. Scarcely any fragrance. Bloom moderate. Burns badly. Plant of tall, slender growth.
Remarks — Stock pure and true to type.

VERMILION BRILLIANT

Originated by Burpee. *Introduced by* Burpee, 1912.

Donated by Burpee, Boddington, 1912.

Description in detail — Color of standard crimson-red 114 (1–3); wings crimson-red 114 (1 or lighter). Flower large, waved form; standard large, waved slightly; wings short and broad. Flowers two to three, irregularly placed on long, strong stems. Moderately fragrant. Moderately productive. Plant of tall, strong growth.. Leaflets broad, pointed.

Striped and Flaked (Chocolate on gray ground)

SENATOR SPENCER

Originated by ————. *Introduced by* Burpee, 1910.

Donated by Burpee, Morse, 1910; Burpee, 1911, 1912, 1913.

Description in brief — A large garden or exhibition variety, with chocolate-colored stripes on a white ground.

Description in detail — Color purple-brown 166 (1–2) stripes on a purplish-tinted white 6 (2) ground. Standard large, round, Spencer-waved; wings long and broad, waved. Flowers two to four, on long, strong stems. Fragrant. Bloom profuse, continuous. Sunproof. Growth medium, stout, healthy. Seed very large, black.

Remarks — In 1910 the introducer's stock was fixed. The other stock contained Aurora. Later stocks were correct.

Striped and Flaked (Orange-scarlet stripes)

AURORA SPENCER

Originated by ————. *Introduced by* Burpee, Morse, 1909.

Donated by Burpee, Morse, 1910; Burpee, 1911, 1912, 1913.

Description in brief — A large, waved, salmon-pink-striped variety, for garden, market, or exhibition use.

Description in detail — Color of stripes on standard salmon-pink 126 (4), on a creamy white ground; wings deep cerise 123 (1–3). Standard large to very large, Spencer-waved; wings large, waved, concealing the keel. Flowers two to three, on strong stems of medium length. Fragrant. Bloom profuse, continuous. Sunproof. Plant of strong, healthy growth.

Remarks — The standard variety of this color.

MAGNIFICENT

Originated by Miller. *Introduced by* Miller, 1910.

Donated by Miller, 1910.

Description in brief — A large, waved, salmon-pink-striped, garden variety.

Description in detail — Creamy white 10 (1) ground, with salmon-pink 126 (4) stripes on standard and deep cerise 123 (1–3) on wings. Standard large, waved; wings large to very large, waved, standing out at right angles to the standard, concealing the keel. Flowers two to three, on stems of moderate length. Fragrance moderate. Bloom profuse. Blackens in bright sunshine. Plant strong, vigorous, healthy.

Comparison — Same color as Aurora Spencer, and not affected by the sun.

Remarks — A fixed stock.

MRS. W. J. UNWIN

Originated by Unwin. *Introduced by* Unwin, 1911.

Donated by Unwin, for advance trial.

Description in brief—A large flower, striped with bright rosy scarlet; for garden, market, or exhibition use.

Description in detail — Color of stripes on standard bright rosy scarlet 124 (4); on wings almost carmine-lake 121 (1), but more salmony. Standard large, Spencer-waved; wings large, waved, partly open. Flowers three, on long, strong stems. Fragrance slight. Bloom profuse, continuous. Plant of strong, healthy growth.

Comparison — Color deeper and brighter than Aurora.

Remarks — A fixed stock. This variety is not synonymous with Aurora, as is sometimes reported; repeated trials indicate that it is distinct.

STARK'S ELEGANCE

Originated by Stark. *Introduced by* Stark, 1909.

Donated by Rawson, 1910.

Description in brief — A medium-sized flower, striped with rosy scarlet; a garden variety.

Description in detail — Color of stripes on standard bright rosy scarlet 124 (2–3); on wings 124 (1–2). Standard of medium size, upright; wings hooded, upright, long and narrow, concealing the keel. Flowers two to three, on short stems. Slight fragrance. Bloom free. Burns slightly. Plant of medium height and slender growth.

Comparison — Inferior to Aurora Spencer.

Remarks — Contained one plant of Salopian. Has no value.

Striped and Flaked (Pink on primrose ground)

ETHEL ROOSEVELT

Originated by ——————. *Introduced by* Burpee, 1911.

Donated by Burpee, for advance trial, 1910, under name Lottie Hutchins Spencer.

Description in brief — Large, waved, primrose striped with light pink; a garden or exhibition variety.

Description in detail — Color pale lilac-rose 130 (4) stripes on a yellowish white 13 (2–3) ground. Standard large, waved; wings large, long and broad, partly open. Flowers two to three, on medium stems. Slightly fragrant. Bloom profuse. Sunproof. Plant of medium height and slender, healthy growth.

Remarks — A fixed stock. Sent out as Ethel Roosevelt in 1911.

MRS. H. D. TIGWELL

Originated by Unwin. *Introduced by* Unwin, 1911.

Donated by Unwin, for advance trial, 1910.

Description in brief — A large, waved flower, pink-striped on a creamy white ground.

Description in detail — Color pale lilac-rose 130 (4) stripes on a creamy white 10 (4) ground. Standard large, slightly waved; wings large, drooping, concealing the keel. Poor substance. Some flowers do not open. Flowers two to three, on moderately long, strong stems. Mild fragrance. Bloom fair. Plant of tall, vigorous growth. Color in axils of leaves.

Comparison — Similar in color to Ethel Roosevelt, but of poor substance.

Remarks — A pure stock.

Senator Spencer

White Spencer

ZENA

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief —A large garden variety, with red flakes on a creamy white ground.

Description in detail —Color pale lilac-rose 130 (4) on a yellowish white 13 (2–3) ground. Standard large, very slightly waved; wings large, partly open. Flowers three, on moderately long, strong stems. Bloom profuse. Plant of medium height and slender, healthy growth.

Comparison — Similar in color to Ethel Roosevelt.

Remarks — Contains a large number of mauve-striped flowers.

Striped and Flaked (Purple and blue)

APRIL

Originated by Dipnall. *Introduced by* Dipnall, 1913.

Donated by Dipnall, 1912, 1913.

Description in brief — A large, waved, blue-striped variety.

Description in detail — Color of standard and wings light bluish violet 202 (1–4) flaked and striped on a white ground. Flower large, waved form; standard large, slightly waved; wings large, long and narrow, spreading. Substance good. Flowers two to three, on medium stems. Moderately fragrant. Bloom not profuse. Plant of tall, stout, healthy growth. Leaflets broad, round, dark green.

Comparison — Quite distinct from Bertie Usher.

Remarks — Stock pure, true.

BERTIE USHER

Originated by Usher. *Introduced by* Usher, 1912.

Donated by Sutton, 1912, 1913.

Description in brief — A large, waved flower, striped with violet-purple.

Description in detail — The standard and wings are striped and flaked with violet-purple 192 (1) on a white ground. Flower large, waved form; standard large, slightly waved; wings short and broad. Flowers three, equidistant on long, strong stems. Moderate fragrance. Moderately productive. Sunproof. Plant of very tall, stout growth. Leaflets broad, pointed; tendrils green.

Comparison — Similar in color to Loyalty, but has smaller flowers and is a less vigorous plant.

BLUE FLAKE

Originated by Unwin. *Introduced by* Unwin, 1910.

Donated by Unwin.

Description in brief — Light blue flake on white, Unwin form; a large garden variety.

Description in detail — Flower opens with considerable mauve in the color, but changes to Parma violet 200 (1–2) stripes on the standard and 200 (2–3) on the wings, with a lilacy white 7 (2) ground. Standard medium to large, Unwin form; wings large, hooded, concealing the keel. Flowers two to three, on medium stems. Fragrant. Bloom profuse, continuous. Plant of tall, strong, healthy growth.

Comparison — Distinct from Paradise Blue Flake.

Remarks — A pure stock.

BLUE FLAKE SPENCER

Originated by Box. *Introduced by* Box, 1912.

Donated by Box, 1912.

Description in brief — A large, blue-flaked variety.

Description in detail — Color of standard and wings violet-purple 192 (1–4). Flower large, waved form; standard large, much waved; wings long and broad, spreading. Substance good. Flowers three, on long, strong stems. Moderately fragrant. Bloom not profuse. Plant tall, strong. Leaflets broad, round; tendrils green.

GEORGE CURZON

Originated by Aldersey. *Introduced by* Aldersey, 1912.

Donated by Aldersey, 1912.

Description in brief — Dark blue flake.

Description in detail — Standard and wings have bright bluish flakes on a white or pale lavender ground. Flower large, waved form; standard large, slightly waved; wings long and broad, spreading. Flowers three, equidistant on medium stems. No fragrance. Bloom moderate. Sunproof. Plant of tall, strong growth. Leaflets broad, pointed; tendrils green.

Comparison — Not equal to Loyalty.

LOYALTY

Originated by Stark. *Introduced by* Stark, 1912.

Donated by Stark, 1912.

Description in brief — A purple-violet flake on a white ground.

Description in detail — The standard and wings are striped purple-violet 192 (1) on a white ground. Flower very large, waved form; standard very large, much waved; wings short, broad. Substance good. Flowers three, on medium stems. Moderate fragrance. Bloom profuse. Plant of very tall, stout growth. Leaflets broad, pointed.

Comparison — Like Senator, except striped with blue. Better than Blue Flake Spencer.

Remarks — The finest blue stripe. Stock pure, true.

PARADISE BLUE FLAKE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief — A large flower, having clear blue stripes on a white ground.

Description in detail — A purplish-tinted white 6 (3–4) ground, with Parma violet 200 (3–4) stripes on standard and ageratum blue 201 (1–2) on wings. Standard large, Spencer-waved; wings hooded, long and broad, concealing the keel. Flowers three, on long stems of moderate strength. Fragrant. Bloom profuse, continuous. Plant of tall, very vigorous growth.

Comparison — Opens with less mauve, is less striped, and shows more white ground than Blue Flake.

Remarks — A fixed stock.

Striped and Flaked (Red on white ground)

AMERICA SPENCER

Originated by ——————. *Introduced by* Burpee, 1911.

Donated by Burpee, 1913.

Description in brief — Large, waved, red-flaked on a white ground.

Description in detail — Color of standard and wings rosy white 8 (1), striped with reddish purple 161 (1). Flower very large, waved form; standard large, waved; wings long and broad, concealing the keel. Flowers usually three, on strong, short stems. Moderately fragrant. Moderately productive. Sunproof. A garden or exhibition variety. Plant of medium height and stout, healthy growth. Leaflets dark green, broad, pointed; tendrils green.

GAIETY SPENCER

Originated by Morse. *Introduced by* Burpee, 1912.

Donated by Burpee, Morse, 1912.

Description in brief — A waved variety.

Description in detail — The standard and wings are striped with purple-rose 150 (1) on a rosy white 8 (1) ground. Flower very large, waved form; standard very large, waved, some double; wings large, long and broad. Flowers three to four, well placed on very long, strong stems. Productive. Plant of strong, vigorous growth. Foliage rich dark green; tendrils colored; color in axils of peduncles and leaflets.

JACK UNWIN

Originated by Unwin. *Introduced by* Unwin, 1909.

Donated by Unwin, 1910.

Description in brief — A large, waved, red-striped variety, for garden or exhibition use.

Description in detail — Color of stripes Rose Neyron red 119 (2–3) on a white ground. Standard large, slightly waved; wings large, hooded, concealing the keel. Flowers two to four, on long stems of moderate strength. Fragrant. Bloom profuse. Sunproof. Plant of medium height and strong, healthy growth. Color in axils of leaves.

Comparison — The Unwin form of Mrs. Joseph Chamberlain.

Remarks — A fixed stock.

PARADISE RED FLAKE

Originated by Miss Hemus. *Introduced by* Miss Hemus, 1908.

Donated by Miss Hemus, 1910.

Description in brief — A large, red-striped variety.

Description in detail —A rosy white ground 8 (3–4), with stripes of madder carmine 141 (3–4) on standard and carmine-purple 156 (1) on wings. Standard large, upright, open; wings large. Flowers two to three, on moderate stems. Fragrance slight. Plant of strong growth.

Comparison — A heavier stripe than Jack Unwin. Very distinct from America in color.

Remarks — A pure stock.

RAINBOW SPENCER

Originated by Morse. *Introduced by* Morse, Burpee, 1912

Donated by Burpee, Boddington, Morse, 1912.

Description in detail — A faint pink stripe on white. Flower very large, waved form; standard very large, waved; wings very large. Flowers on long, very strong stems. Plant of strong, vigorous growth.

Comparison — Larger than Gaiety Spencer.

Remarks — All stocks were one half to three fourths Gaiety Spencer.

RAMONA SPENCER

Originated by Morse. *Introduced by* Morse, 1909.

Donated by Boddington, Morse, 1910; Burpee, 1911, 1912.

Description in brief — A medium to large, waved flower, striped with pale rosy pink; a garden variety.

Description in detail — Color of stripes rosy pink 118 (1) on a rosy white 8 (1) ground. Standard medium to large, waved; wings of medium size, waved, concealing the keel. Flowers two to three, on fair stems. Moderately fragrant. Bloom profuse, continuous. Plant of moderately vigorous, healthy growth. Flowers fade, becoming almost white.

Comparison — Rosabelle Hoare is a deeper stripe. Later stocks of this variety are superior to those of 1910 and have superseded Rosabelle Hoare.

Remarks — Too pale a stripe.

RED FLAKE SPENCER

Originated by ————. *Introduced by* Henderson, 1910.

Donated by Henderson, 1910.

Description in brief — A red stripe on a white ground.

Synonyms — Synonymous with America.

Remarks — A mixed stock.

ROSABELLE HOARE

Originated by Unwin. *Introduced by* Unwin, 1909.

Donated by Unwin, 1910.

Description in brief — A large, flaked variety, Unwin form.

Description in detail — Ground color rosy white 8 (4), with stripes of Rose Neyron red 119 (1–2) on standard and rosy pink 118 (1–2) on wings. Standard large, Unwin form; wings large, hooded, concealing the keel. Flowers three, on strong stems of moderate length. Fragrant. Bloom profuse, continuous. Sunproof. Plant of strong, healthy growth.

Comparison — Flowers deeper-colored than Ramona Spencer. After 1910 Ramona Spencer was so much improved as to supersede Rosabelle Hoare.

Remarks — A fixed stock.

UNCLE SAM

Originated by Burpee. *Introduced by* ————.

Donated by Burpee, for advance trial.

Description in brief — A large, waved flower, with deep red stripes; a garden variety.

Description in detail — Color of stripes on standard geranium red 111 (1), on wings 111 (1–2), on a white ground. Standard large, slightly waved; wings large, partly open. Flowers two to three, on moderately long, strong stems. Plant of moderately tall, vigorous growth.

Comparison — Superior in size to Red Flake Paradise.

Remarks — A fixed stock. Should have been introduced in 1911, as it was then the best crimson-striped variety.

Striped and Flaked (Rose on primrose ground)

ZEBRA

Originated by Biffen. *Introduced by* Miss Hemus, 1910.

Donated by Miss Hemus, 1910.

Description in brief—Large, "reddish mauve flake" on a creamy white ground; a garden or exhibition variety.

Description in detail — Standard striped with violet-rose 154 (3–4), wings with 154 (1–2), on a creamy white 10 (1–2) ground. Standard large, waved; wings long and broad, partly open. Flowers two to three, on strong stems. Moderate fragrance. Bloom free. Burns slightly. Plant of medium height and stout, healthy growth.

Remarks — A pure stock. Distinct in color from the other varieties here listed.

White

ALTHORP WHITE

Originated by Cole. *Introduced by* Cole, 1910.

Donated by Cole.

Description in brief — A large, pure white, waved variety, for garden or exhibition use.

Description in detail — Color milk white 11 (2–3). Standard large, Spencer-waved, with round top; wings short, broad, partly open, waved. Flowers three, on long, strong stems. Moderately fragrant. Bloom profuse. Plant of moderately strong, healthy growth. Seed white.

Synonyms — A synonym of Etta Dyke.

Remarks — Stock pure.

ETTA DYKE

Originated by Breadmore. *Introduced by* Breadmore, 1908.

Donated by Boddington, Dobbie, Rawson, Unwin, 1910.

Description in brief — A large, pure white, Spencer-waved variety.

Description in detail — Color of standard and wings milk white 11 (3–4). Flower large, waved form; standard large, much waved; wings long and broad, concealing the keel. Flowers three to four, irregularly spaced on long, strong stems. Very fragrant. Bloom profuse. Plant of medium height and strong, healthy growth. Tendrils green. Seed white.

Comparison — Similar to the best strains of Burpee's White Spencer.

Remarks — The English stocks of this variety in 1910 were superior to the American, not only in amount of waviness but also in purity of stock.

FLORENCE WRIGHT SPENCER

Originated by Stark. *Introduced by* Stark, 1913.

Donated by Stark, 1912.

Description in brief — A large, waved, white variety.

Description in detail — Opens yellowish white 13 (1–2), fading to pure white. Flower very large, waved form. Substance good. Flowers three to four, on long, stout stems. Plant of tall, vigorous growth. Foliage dark green.

Comparison — A superior strain of Florence Wright.

MRS. SANKEY SPENCER

Originated by Morse. *Introduced by* Morse, 1909.

Donated by Boddington, Morse, 1910.

Description in brief — A large, waved, white variety.

Description in detail — Color milk white 11 (1–2); shows a tinge of pink in opening buds, but fades to white. Standard large, Spencer-waved; wings long and broad, partly open. Flowers two to four, on long, strong stems. Fragrant. Bloom profuse, continuous, lasting well on plant. Sunproof. Plant of strong, vigorous growth. Seed large, round, dark brown.

Remarks — One stock pure.

MONEYMAKER

Originated by Agate. *Introduced by* Agate, Lumley, 1910.

Donated by Farquhar, 1913.

Description in brief — A very large, waved, white variety.

Description in detail — Color snow white 2 (1). Flower very large, waved form; standard very large, slightly waved; wings large, short and broad. Flowers three, on long, strong stems. Fragrance moderate. Moderately productive. Sunproof. Plant of tall, stout growth. Leaflets broad, round, dark green.

Remarks — Stock pure, true.

NORA UNWIN

Originated by Unwin. *Introduced by* Unwin, and Watkins & Simpson.

Donated by Boddington, Dobbie, Rawson, Unwin, and Watkins & Simpson.

Description in brief — A large, pure white, waved variety, for garden or market use.

Description in detail — Color milk white 11 (3–4). Standard large, slightly waved, with round top; wings long and broad, concealing the keel. Flowers two to four, mostly three, on long, strong stems. Moderately fragrant. Bloom profuse, continuous. Plant of tall, strong, healthy growth. Seed white. Germination forty to seventy-five per cent.

Remarks — A standard white variety.

SNOWDON

Originated by ————. *Introduced by* Watkins & Simpson, 1913.

Donated by Boddington, 1913.

Description in detail. — Color of standard and wings snow white 2 (1). Flower large, waved form; standard large, waved; wings short and broad, concealing the keel. Flowers three, on stems of medium length. Moderate fragrance. Bloom medium. Sunproof. Plant of tall, slender growth. Leaflets broad, round, dark green.

Remarks — Stock pure, true.

WHITE QUEEN

Originated by Stark. *Introduced by* Stark, 1912.

Donated by Stark, 1912.

Description in brief — A large, waved, white variety.

Description in detail — Opens yellowish white 13 (1), fading to pure white. Flower large. Flowers three to four, on very long, strong stems. Plant tall, very vigorous. Foliage dark green, healthy.

Comparison — Superior to White Spencer.

Remarks — Should be given a trial.

WHITE SPENCER

Originated by Routzahn. *Introduced by* Burpee, 1908.

Donated by Boddington, Henderson, Morse, Rawson, 1910.

Description in brief — Large, pure white, waved, productive; a garden, market, and exhibition variety.

Description in detail — Color of flower milk white 11 (3–4). Standard large, Spencer-waved, with round top; wings long and broad, waved, partly open. Flowers two to four, usually three, on long, strong stems. Fragrant. Bloom profuse. Midseason. Plant of tall, healthy, vigorous growth. Seed white. Germination seventy to eighty per cent.

Synonyms — The true flowers of this variety are identical with Etta Dyke, under which name it is known in England.

Remarks — Two of the stocks received in 1910 were pure as to color, but all gave some flowers that were not of the waved form. A standard white variety.

THE BEST VARIETIES OF SWEET PEAS

The following list includes our selection from the hundreds of varieties tested under New York conditions. It is a matter of personal taste whether some of the color sections are desirable for any particular garden; however, it is easily possible to select those varieties that are suited to individual tastes.

WAVED VARIETIES

Bicolor — Mrs. Cuthbertson, Colleen.
Blue — Margaret Madison, Flora Norton Spencer, Blue Jacket.
Blush — Lady Evelyn Eyre, Princess Victoria, Florence Morse Spencer.
Carmine — John Ingman.
Cerise — Chrissie Unwin.
Cream, Buff, and Ivory — Primrose Spencer, Isobel Malcolm, Primrose Beauty, Lady Knox Queen Victoria Spencer.
Cream-pink (Deep) — Mrs. Gibbs Box, Constance Oliver.
Cream-pink (Pale) — Mrs. Routzahn, Lady Miller, Mrs. Hugh Dickson.
Crimson — King Edward Spencer.
Fancy — Afterglow.
Lavender — Florence Nightingale.
Magenta — Menie Christie.
Marbled — May Campbell.
Maroon — Nubian, King Manoel.
Maroon-purple — Arthur Green.
Maroon-red — Brunette, Red Chief.
Mauve (Dark) — Tennant Spencer.
Mauve (Pale) — Mrs. Heslington, Mauve Queen.
Orange-pink — Edrom Beauty, Carene, Helen Lewis.
Orange-scarlet — Thomas Stevenson.
Picotee edged (Cream ground) — Evelyn Hemus, Mrs. C. W. Breadmore.
Picotee edged (White ground) — Dainty Spencer, Elsie Herbert, Martha Washington.
Pink (Deep) — Hercules, Countess Spencer.
Pink (Pale) — Elfrida Pearson.
Rose — Marie Corelli, Rosabelle.
Salmon Shades — Stirling Stent, Melba, Barbara.
Scarlet — Dobbie's Scarlet, Scarlet Emperor, Red Star.
Striped and Flaked (Chocolate on gray ground) — Senator Spencer.
Striped and Flaked (Purple and blue) — Loyalty.
Striped and Flaked (Red and rose) — America Spencer, Aurora Spencer, Mrs. W. J Unwin.
White — White Spencer, Nora Unwin.

VARIETIES OF OPEN AND HOODED FORMS

Bicolor — Blanche Ferry, Jeannie Gordon.
Blue — Brilliant Blue, Navy Blue.
Blue (Light) — Flora Norton.
Blush — Modesty.
Cerise — Coccinea.

Cream, Buff, and Ivory — Zarina, The Honorable Mrs. E. Kenyon, Queen Victoria.
Crimson — King Edward VII.
Lavender — Lady Grizel Hamilton.
Marbled — Helen Pierce.
Maroon — Black Knight, Othello.
Mauve — Admiration, Mrs. Walter Wright, Dorothy Tennant.
Orange Shades — Henry Eckford, Miss Wilmott.
Picotee edged — Dainty, Lottie Eckford, Phenomenal.
Pink — Prima Donna, Lovely, Katherine Tracy, Janet Scott.
Rose and Carmine — Lord Roseberry.
Scarlet — Queen Alexandra.
Striped and Flaked (Chocolate on gray ground) — Senator.
Striped and Flaked (Purple and blue) — Princess of Wales, Hester
Striped and Flaked (Red and rose) — America, Aurora, Ramona.
White — Dorothy Eckford, Shasta, Emily Henderson, White Wonder.

EARLY-FLOWERING VARIETIES

Bicolor — Earliest of All.
Blue — Le Marquis (described in Bulletin 319 of this station, page 655).
Lavender — Mrs. Alexander Wallace (described in Bulletin 319, page 653).
Primrose — Earliest Sunbeams.
Salmon-pink — Mrs. William Sim (described in Bulletin 319, page 648).
White — Earliest White, Mont Blanc.

MARKET VARIETIES

Open and hooded varieties — Dorothy Eckford, King Edward VII, Brilliant Blue, Lady Grizel Hamilton, Prima Donna, Blanche Ferry.
Waved varieties — Countess Spencer, Nora Unwin, Asta Ohn, King Edward Spencer.

The market requires flowers of good substance, so that they will endure handling, and in good, clear colors. Pink, Pink and White, Lavender, and Red and White varieties are most in demand and these should comprise the greater part of the plantings. A few of the Blue, Cream-pink, and Primrose varieties may be sold. The number of blooms of the last-named that may be disposed of will depend on the market. The early-flowering varieties mentioned above are suitable for market.

INDEX TO VARIETIES

APRIL, 1914 BULLETIN 343

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Plant-breeding

OATS FOR NEW YORK

By H. H. LOVE

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Experimenting Staff

The regular bulletins of the Station are sent free to persons residing in New York State who request them.

OATS FOR NEW YORK[1]

H. H. Love

(In cooperation with the Bureau of Plant Industry, United States Department of Agriculture)

(*Received for publication February 11, 1914*)

The data herein presented are the result of the joint work of several persons. The work was begun by J. B. Norton, who had charge of it during the first year. During the second year and part of the third year Dr. H. J. Webber had charge of the work and was assisted by E. P. Humbert. In the latter part of the third year and at the beginning of the fourth year, 1910, the author assumed charge of the experiments, in which he has been ably assisted by C. E. Leighty, W. T. Craig, J. R. Livermore, Anna M. Atwater, and H. W. Teeter.

This paper is published as a report of progress. The data relating to the test of the series of hybrids and selections that is now drawing to a close are given, as well as some data on varieties that are serving as a basis for new selections and hybrids, which are in their second year.

Oats constitute one of the most important field crops of New York State. According to the statistics for different crops in 1912, taken from the Yearbook of the United States Department of Agriculture, the oat crop was third in farm value in New York State. Hay ranked first, with a farm value of $87,910,000; potatoes second, with a value of $22,133,000; and oats third, with a value of $15,420,000 — New York ranking eleventh in oat production in the United States. For the year 1912 New York ranked twelfth in total acreage planted with oats, thirteenth in total yield, and twenty-ninth in average yield per acre. The average yield per acre was 30.8 bushels. For the years 1900 to 1909, New York ranked nineteenth in average yield per acre, which was 31.3 bushels. This yield is low, and effort should be made to increase it. The average yield for each county in the State in 1909 is shown in Fig. 25. These yields were obtained from the report of the Thirteenth Census of the United States.

Oats are valuable to farmers because they fit in well with the many systems of crop rotation used in this State. Oats are also much used as a nurse crop when land is to be seeded to grass; the value of such a crop is doubtful, however, for many nurse crops are robber crops.

Since oats form one of the most valuable field crops of the State, it is important to increase the production by increasing the yield per acre.

[1] Paper No. 46, Department of Plant-breeding, Cornell University, Ithaca, New York.

Better methods of culture and the use of better varieties for seeding purposes will aid materially in increasing production. For the past seven years experiments have been conducted by the Department of Plant-breeding at Cornell University in cooperation with the Bureau of Plant Industry of the United States Department of Agriculture, in order to improve the yield and other qualities of oats. The oat-breeding plats on the experiment station farm, from which some of the following results have been obtained, are shown in Fig. 26.

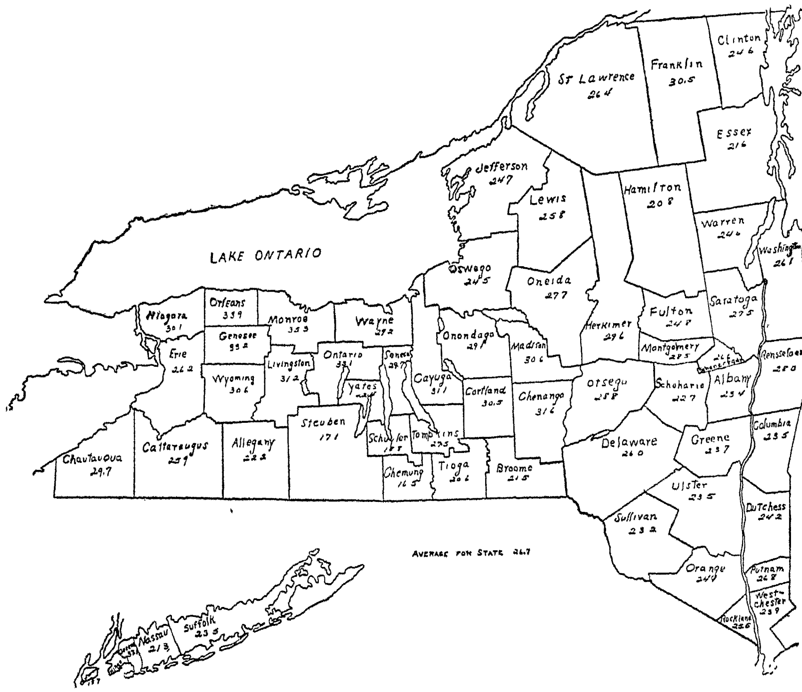

FIG. 25.— *Map of New York State, showing average yields of oats for 1909 in the different counties*

MATERIAL USED

The material used has been of two kinds: first, a series of strains consisting of hybrids and selections made by J. B. Norton while he was connected with the Bureau of Plant Industry; and, second, a large number of commercial varieties, which were compared with the above strains and which will furnish a basis for further selections and hybridizations.

The hybrids and selections mentioned were made to a large extent by Mr. Norton in Illinois, where the climatic conditions differ considerably from those of New York. The result was that, in the main, early varieties were used as foundation stock. A series of these hybrids and selections

was brought to the Cornell University Agricultural Experiment Station in 1907, to be tested for the determination of their possible value as good yielding varieties for New York conditions.

The first crop of this series was grown in 1907 and the testing of the different strains has been continued to the present time. Since the experiments with the hybrids and selections have been conducted for seven years, the crops have been grown under very different climatic conditions, and considerable data of value have been collected. The

FIG. 26.—*View of oat-breeding plats of the Department of Plant-breeding at Cornell University*

tests have also been conducted for a long enough time so that definite information concerning the comparative merits of the different strains is now at hand, and a large number of these strains, which have proved worthless for New York, may be discarded.

METHODS USED

All the strains have been grown and tested by the rod-row system throughout the experiments. By the rod-row method the different strains are sown in rows rather than in plats. The exact length of the

rows has varied from time to time; at present the rows are sixteen feet in length and one foot apart. At harvesting time six inches are cut from each end of the row, leaving a fifteen-foot row on which to base the calculations. It is obvious that the end of each row is cut off so that more uniform conditions may be obtained and so that the effect of increased nutrition which occurs at the ends will not enter into the calculations and affect the results. By using a fifteen-foot row and weighing the grain in grams, the calculated yield in bushels per acre is obtained by multiplying the number of grams per row by .2 (grams per row $\times$ .2 = bushels per acre).[2]

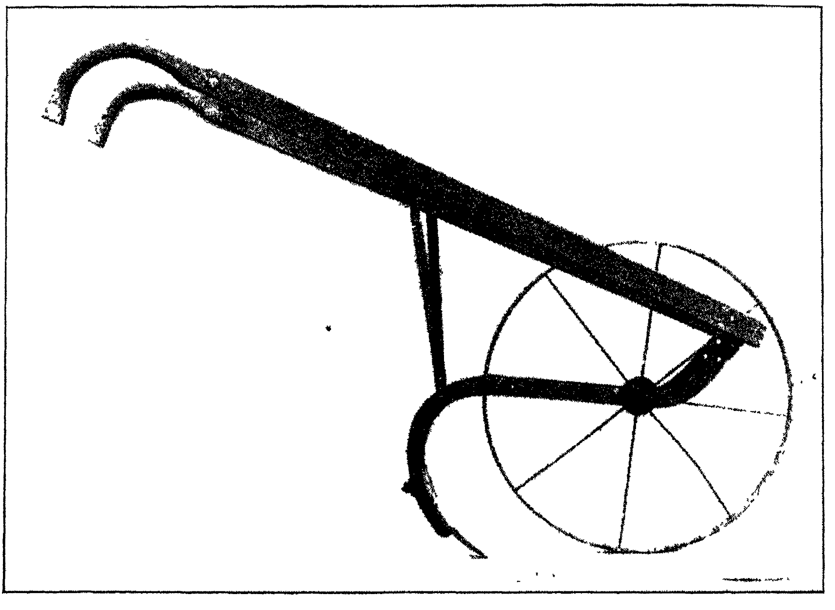

FIG. 27.— *Plow used in opening furrows for rod rows*

The amount of seed required for each row is weighed into separate envelopes before planting time.

When it is time to sow, the field is marked off with a sled marker and the rows are opened up with a small plow, shown in Fig. 27. The seed is scattered by hand, for it has been found that for short rows seeding by hand can be done fairly rapidly, very uniformly, and much better than by machinery. It has been demonstrated that with a force of five men — one to mark and open the furrows, one to cover, and three to sow — one thousand to twelve hundred rows may be sown in a day. In the begin-

[2] The exact factor is .20006613+.

ning of the work only one row of each strain was grown, but it has been found that the same strain should be repeated in as many rows in different parts of the field as is feasible. Beginning in 1909 the different strains were repeated several times, and they have been so repeated each year since that date. After trial of different systems it has been decided to test each variety, or strain, ten times. Any number of tests less than ten is considered too small, and the fact that the average of all rows is easily obtainable with ten as a divisor makes it all the more desirable to use this number. Every tenth row of the series is a check row and is sown with the same kind of seed in order to determine the variability of the soil.

In regard to the use of rod rows for the testing of strains, it may be said that of all the systems tried this method seems to be the best. This is especially true on soil that is not very uniform. It is not sufficient to draw conclusions from one plat of a variety, for the plat may be favorably or unfavorably located and the results influenced thereby. Concerning this point, attention may be called to the work of Dr. T. L. Lyon. After comparing the errors obtained from rod rows and one-tenth-acre plats he concludes: " The advantage from the small plats is not only in point of accuracy, but also in the area of land required. Seven one-tenth-acre plats covered an area of 30,492 square feet while seventy of the seventeen-foot rows required only 1190 square feet. The use of the row method in variety testing is commended by the results of this test."[3] Montgomery[4] has found that the use of the row method for the testing of varieties is accurate when the rows are repeated a number of times. His results show a good correlation between the results obtained from field tests and those from row tests.

It may be interesting to note here the close agreement between the same varieties when grown in rod rows in different parts of the field. To be sure, the yield is affected by the change in the soil, being high or low depending on the fertility of the soil. The relative yields of the varieties in different parts of the field is seen in Fig. 28, which shows the increase or the decrease in relation to the variety used as the check. The check is the same variety throughout the tests and is plotted here as the base line. The yields of the different varieties have been obtained and their gain or loss in relation to the check is here plotted. The yield of the check has been assumed as the base line in order to represent graphically the gain or the loss of the different strains. The yields for the same strain from three different parts of the field are plotted on the same ordinates. From a study of this chart it is seen that with a few exceptions the different varieties yield either comparatively high or com-

[3] American Society of Agronomy. Proc. 2:38–39. 1910.

[4] Montgomery, E. G. Experiments in wheat breeding: Experimental error in the nursery and variation in nitrogen and yield. U. S. Plant Indus. Bur. Bul. 269:1-61.

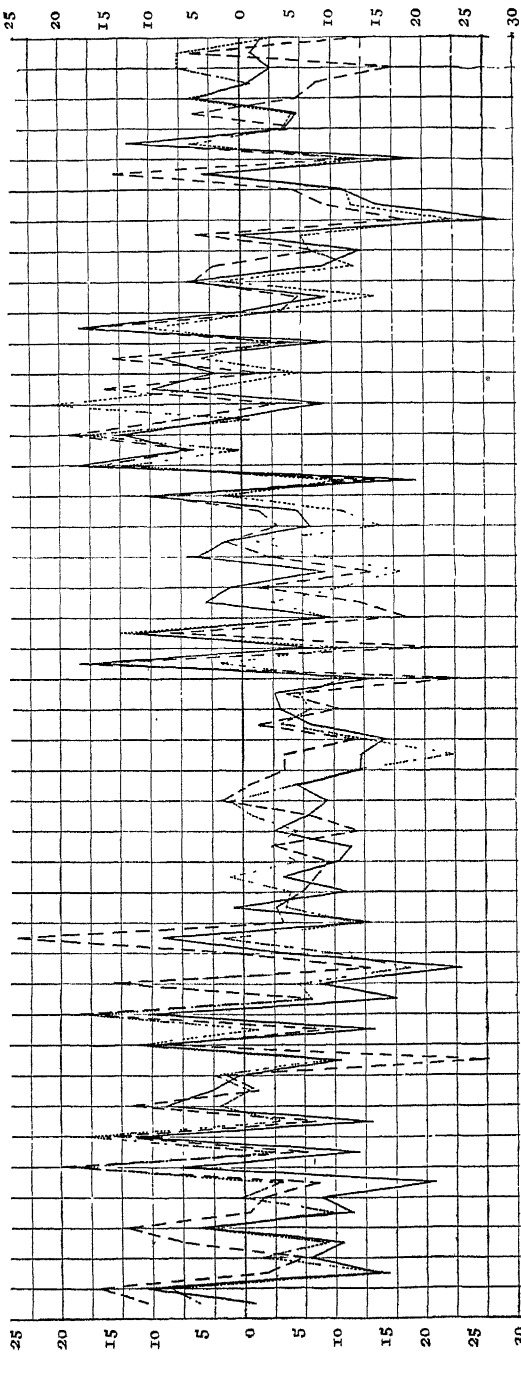

FIG. 28.— *Differences above and below check yields when the same varieties are grown in different parts of the field*

paratively low in the different parts of the field. This furnishes more evidence as to the reliability of the rod-row system for the testing of varieties.

When the crop is ripe and ready for cutting, each row is cut and tagged separately (Fig. 29). The bundles are then moved to a building where they are carefully dried for threshing. The threshing is done by means of a small threshing machine (figures 30 and 31) designed for this purpose by H. W. Teeter. The machine consists of a cylinder, a very coarse

FIG. 29.—*Harvesting rod rows of oats on the plant-breeding plats of the Cornell University Agricultural Experiment Station*

riddle, and a fan. The construction is simple and is designed primarily to thresh the grain without any mechanical mixture. The machine can be easily cleaned after each row or variety is threshed, since the lid may be raised, bringing into plain view all inside construction so that a single remaining seed can be seen and easily brushed out. With this machine one can thresh a rod-row sample a minute.

If for any other purpose the grain needs extra cleaning, this is done by means of a small counter seed-cleaner manufactured by A. T. Ferrell

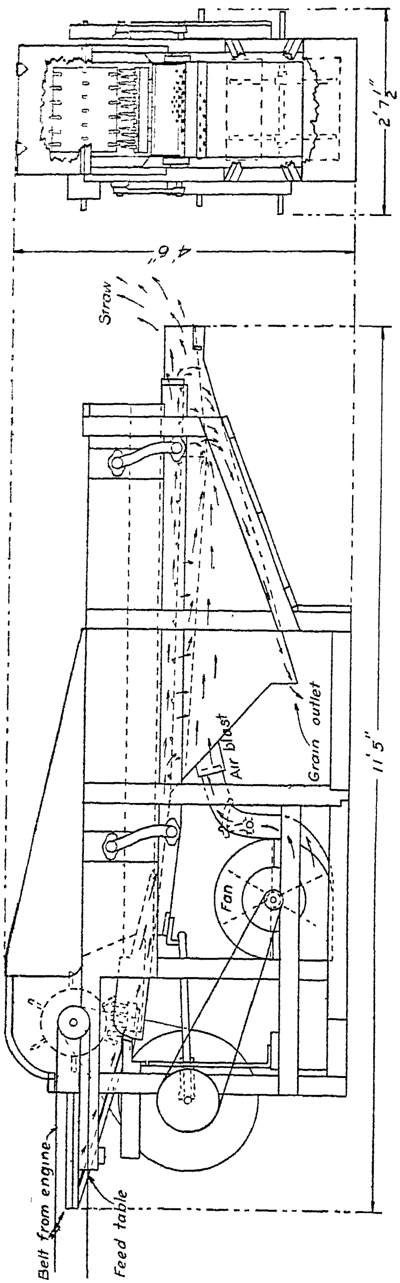

FIG. 30.— *Machine used in threshing rod rows of small grains*

& Co., of Saginaw, Michigan. This machine is very efficient and cleans the grain well, and also cleans itself, so that there is very little opportunity for mixing. The machine is small and can be turned over and shaken after each row is run through, thus further preventing any mixing (Fig. 32).

SOIL

In the first year the crop was grown on soil of the Dunkirk clay loam type. In the second year it was found necessary to grow the crop on a different soil, a gravelly loam, but for the past four years the strains have been grown on the clay loam. In 1910 a series of the tests was also grown on the gravelly loam, in order to see whether there was any difference

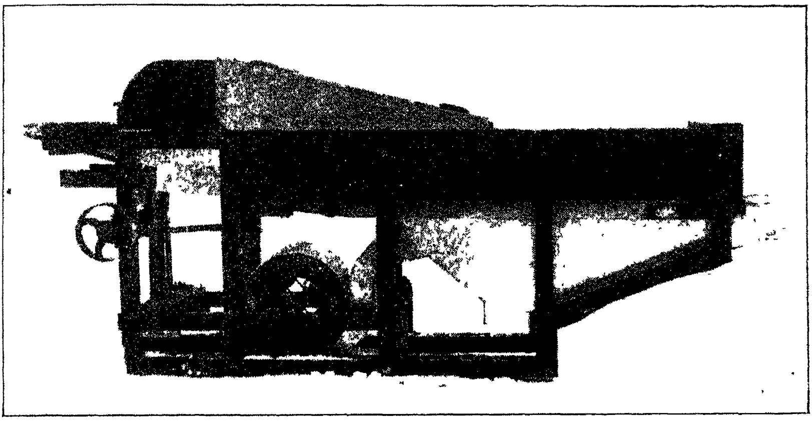

FIG. 31.— *Machine used in threshing rod rows of small grains*

in the results from the two types of soil. It may be stated here that the main difference was that the various strains did not yield so well on the gravelly loam as they did on the clay soil; otherwise the results were similar. For the years 1911, 1912, and 1913 all the rows were grown on the Dunkirk clay loam. As the experiments have progressed, an effort has been made to make the conditions as uniform as possible. The soil was fertilized with only a moderate amount of fertilizer, an attempt being made to duplicate ordinary cultural conditions as nearly as possible.

STRAINS TESTED

The following table gives the series numbers for the different classes of hybrids and selections, together with the varieties that were used as parent strains, either for crossing or as a basis for selection:

TABLE 1. CLASSES OF HYBRIDS AND SELECTIONS

Series number	Varieties used
3	Golden Giant × Asia Minor Rustproof (3676)
8	Clydesdale × Asia Minor Rustproof (3676)
27	Garton's Tartar King × Clydesdale
30	Burt (Early White) × Clydesdale
31	Burt (Early White) × Texas Red Rustproof
32	Burt (Early White) × Early Champion
33	Burt (Early White) × Burt (Extra Early) (NOTE: 33a1 is a straight Burt selection and in these tests is considered as such.)
34	Burt (Early White) × Sixty Day
38	Burt (Extra Early) × Clydesdale
42	Asia Minor Rustproof (3676) × Clydesdale
44	Asia Minor Rustproof (3676) × Garton's Tartar King
45	Asia Minor Rustproof (3676) × Silvermine
49	Sixty Day × Clydesdale
50	Sixty Day × Probsteier.
51	Sixty Day × European Hulless
52	Sixty Day × Burt (Early White)
62	Sixty Day selections
63	Burt (Extra Early) selections
115–21	Rustproof selection
117–3	Early Champion (Alaska) selection
117–5	Early Champion (Alaska) selection
118–7	Silvermine (Musselshell) selection
120–9	Silvermine (Great Dakota) selection
123–5	Welcome selection
125–3	Silvermine (Great American) selection
125–4	Silvermine (Great American) selection
125–20	Silvermine (Great American) selection
131–19	Pringle's Progress selection
132–2	Sixty Day selection
137–6	Early Champion selection
137–8	Early Champion selection
137–21	Early Champion selection
138–1	Early Champion (Prosperity) selection
138–5	Early Champion (Prosperity) selection
142–1	Gold Mine selection
5938–1	Sixty Day selection

There were twelve different varieties used for the hybrids. In most of the series an early variety was used. For example, Burt was used as one parent in seven out of the sixteen series. The Sixty Day variety was used in five out of the sixteen series. The rustproof strains are later than Sixty Day, as is also the Golden Giant variety.

Eight varieties formed the basis for all the selections. Among the selections more early strains were used than late ones. Silvermine and Welcome are later varieties than Sixty Day or Early Champion, and may be considered medium-season oats. It is clear that, since most of the hybrids and selections were of the early type, they are better adapted to localities where early oats thrive best or to seasons that favor early oats.

RESULTS OF ALL TESTS OF HYBRIDS AND SELECTIONS

There were many different strains to be tested for yield. In the first year 133 different strains were grown and the yields obtained therefrom. Only one row of each strain was grown. In the second year, 1908, 103 strains were grown, and some of these were duplicated. It was recognized however, that owing to soil differences one row is not sufficient to warrant drawing any definite conclusions. Beginning with 1908 every tenth row was used as a check and planted with the same seed, but even then it was apparent that the strains should be repeated several times. Beginning with 1909 the more important strains were repeated as many times

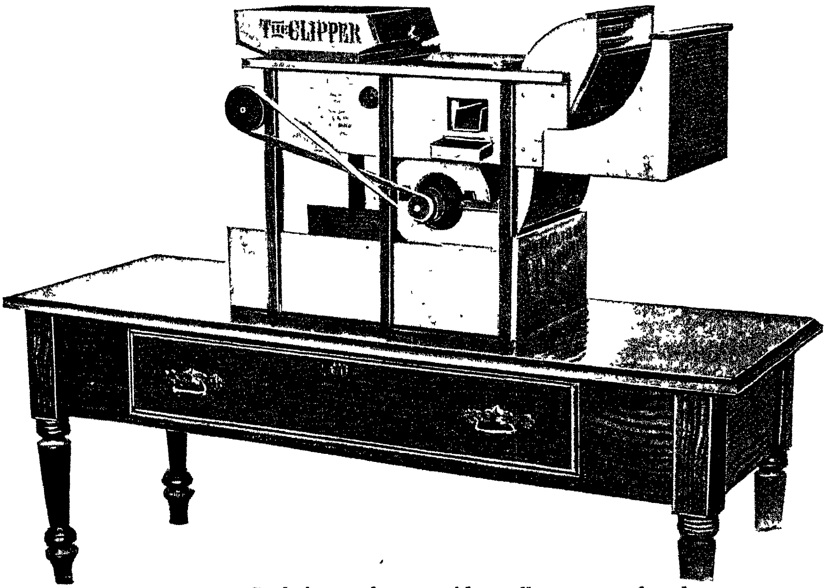

FIG. 32.— *Seed-cleaner for use with small amounts of seed*
(Courtesy of A T. Ferrell Company, Saginaw, Michigan)

as was possible and a check was grown in every tenth row. The facilities for handling such a test have been improved from time to time, so that it is possible to repeat each strain a number of times.

There were 114 strains grown in 1909 and 118 in 1910. In 1911 it was thought best to eliminate many of the strains that had not given a high yield in previous years and only 41 strains were tested in that year, of which 34 were tested twenty-one times.

By discarding so many in 1911 certain strains were eliminated altogether. It was thought best to bring a number of these back into the 1912 test, especially as it was possible to handle many more rows than formerly. There were 108 of these strains tested in 1912 and 39 in 1913.

The complete data for all hybrids or selections tested from 1907 to 1913 are given in Table 2. This table shows the yield by weight for each year and the average yield of each strain for all the years tested. The table is arranged in the ascending order of the series numbers for the hybrids, and the same order for the selections. The yields in this and all other tables are actual yields, or the average yield obtained by averaging the actual yields of all the tests for the strains or the varieties. In this bulletin the experimental errors of the varieties have not been taken into account in the sense that they are calculated and placed in the table. In variety tests or in tests of a similar nature there is always an experimental error affecting the results, since the methods of work are never perfect and many factors influence the actual results from such tests. The author is not unmindful of the value of such a constant, and believes that when possible this should be determined. The experimental error has not been determined here, since in the early work of the testing there was no uniform method of replication and it was thought best not to calculate this for the later tests. This experimental error has been taken into account when the results are interpreted; for example, if two varieties yield 61 and 62 bushels, respectively, the experimental error would not justify a claim that the latter is better than the former unless this is an average of several years and the varieties stand in the same relation each year.

TABLE 2. YIELDS IN BUSHELS PER ACRE OF ALL HYBRIDS AND SELECTIONS TESTED FROM 1907 TO 1913

Pedigree number	Varieties	1907	1908	1909	1910	1911	1912	1913	Average yield
3b1-6	Golden Giant × Asia Minor Rust-	50.0	22.5	41.8	66.0	....	49.0	...	45.9
3b1-10	proof (3676)	30.0		.	.	..	..	...	30.0
3b3-8		50.0	43.7	35.6	69.7	....	51.2	....	50.0
8a2-6-1	Clydesdale × Asia Minor Rust-	.	57.5	40.7	74.5	...	48.0	56.9	55.5
8a2-6-3	proof (3676)	...	42.5	42.2	72.8	..	47.0	....	51.1
8a2-6-4		...	50.0	34.8	73.9	...	48.2	...	51.7
8a2-6-5		37.5	57.5	35.4	75.4	...	50.8	....	51.3
8a2-6-6		..	57.5	36.4	73.8	..	..	....	55.9
8b2-7		32.5	55.0	33.7	66.5	....	59.8	....	49.5
8b3-12-7		45.0	....	..	..	....	.	....	45.0
27a1-27	Garton's Tartar King × Clydes-	....	36.8	32.8	60.2		.	..	43.3
27a1-31	dale	45.0	43.3	47.5	69.8	50.8	64.9	62.4	54.8
30a2-1	Burt (Early White) × Clydesdale	..	....	...	...	36.2	....	...	36.2
30a2-8		52.5	..	....	..	.	...	...	52.5
30a2-12-3		58.7	61.2	34.6	63.5	43.8	51.2	60.4	53.3
30a3-33		57.5	37.5	37.8	66.5	43.8	50.5	...	48.9
31a1-16	Burt (Early White) × Texas Red	38.7	75.0	34.6	66.5	....	44.4	.	51.8
31a1-16-1	Rustproof	46.2	82.5	50.1	64.7	40.2	47.2	53.2	54.9
32a2-1	Burt (Early White) × Early Champion	42.5	62.5	42.8	64.7	39.3	47.2	48.4	49.6
33a2	Burt (Early White) × Burt (Extra	30.0	.	.	.	....	...	....	30.0
33a2-4-3	Early)	40.0	..	30.7	76.2	...	...	....	49.0
33a2-6		25.0	..		...	....	....	....	25.0

TABLE 2 — (*continued*)

Pedigree number	Varieties	1907	1908	1909	1910	1911	1912	1913	Average yield
33a2-7		25.0			...		...	...	25.0
33a2-8-2		40.0			...	...	...	...	40.0
33a2-9		30.0	...	...		...	...	...	30.0
33a2-9-1		40.0		30.0	82.6	...	...	...	50.9
33a2-9-2		47.1	66.2	32.4	67.5	...	56.7	54.2	54.0
33a2-9-3		42.5	...	...	...	...	...	...	42.5
34a1-2	Burt (Early White) × Sixty Day	30.0	...	...	...	...	...	...	30.0
34a1-2-3		37.5	60.0	32.4	59.0	...	33.2	...	44.4
34a1-2-5		40.0	...	...	...	...	...	...	40.0
34a1-2-6		30.0	...	...	...	...	...	...	30.0
34a1-4		32.5	...	...	...	...	...	...	32.5
34a1-5		37.5	...	...	...	...	...	...	37.5
34a1-7		32.5	...	...	...	...	...	...	32.5
34a1-11-1		30.0		...	...	...	...	...	30.0
34a1-11-2		37.5	85.0	53.2	75.0	58.1	57.3	61.8	61.1
34a1-12-1		32.5	...	...	...	...	...	...	32.5
34a1-12-3		47.5	40.0	27.8	69.8	...	46.2	...	46.3
34a1-13		45.0	...	...	...	...	...	...	45.0
34a1-13-1		47.5			...	...	...	...	47.5
34a1-13-3		...	...	36.9	79.2	...	...	...	58.0
34a1-13-4		45.0		...	...	...	...	...	45.0
34a1-13-5		51.9	80.0	31.4	71.8	...	51.0	52.6	56.4
34a1-17		31.2	52.5	25.1	64.2	...	49.8	...	44.6
34a1-18-2		36.2	70.0	39.8	62.2	...	45.4	...	50.7
34a1-18-3		42.5	75.0	36.0	62.4	...	42.0	...	51.6
34a1-19		46.2	52.5	32.0	45.0	...	31.8	...	41.5
34a1-19-1		40.0	90.0	37.8	56.9		42.4	...	53.4
34a1-21		47.5	75.0	31.4	63.0	...	39.6	...	51.3
34a1-22		51.2	50.0	34.7	63.9	...	43.2	...	48.6
34a1-23-1		47.5	75.0	35.2	66.7		39.4	...	52.8
34a1-24		63.7	70.0	50.6	62.5	42.1	43.7	50.8	54.8
34a1-25-4		62.5	40.0	33.4	58.9	...	44.4	...	47.8
34a1-27-2		58.7	69.1	47.0	60.3	43.6	49.1	...	54.6
34a1-27-3		65.0	63.7	48.7	64.0	42.3	49.7	50.9	54.9
34a1-28		35.0	...	18.2	75.5	...	45.8	...	43.6
34a1-28-1		55.0	55.0	32.5	68.9	...	48.0	...	51.9
34a1-28-2		50.0	95.0	38.7	70.6	43.3	43.3	46.0	55.3
34a1-32		63.7	42.5	44.1	81.7	...	45.2	51.5	54.8
34a1-32-1		57.5	85.0	40.9	68.1	43.9	40.5	...	56.0
38a1-9	Burt (Extra Early) × Clydesdale	48.7	48.7	29.8	59.1	...	48.2	54.9	48.2
42a1-1-2	Asia Minor Rustproof (3676) × Clydesdale	46.9	80.0	44.8	59.0	42.1	49.0	47.2	52.7
42a1-3-2		...	52.5	32.9	60.5	...	...	...	48.6
42a1-7		45.0	47.5	30.8	67.5	...	61.0	...	50.4
44b1-13	Asia Minor Rustproof (3676) × Garton's Tartar King	...	55.0	...	...	...	...	...	55.0
45a2-7-2	Asia Minor Rustproof (3676) × Silvermine	50.0	...	...	...	...	...	...	50.0
49a1-7	Sixty Day × Clydesdale	45.0	27.5	36.7	71.4	...	65.0	...	49.1
49a1-25		62.5	63.7	40.6	65.7	...	57.1	46.3	56.0
49a1-26		57.5	34.1	33.5	62.2	...	55.2	...	48.5
49a1-26-3		52.5	32.5	34.6	59.9	...	56.4	...	47.2
49a1-26-7		57.5	40.8	26.7	77.5	...	52.8	...	51.1
49a1-27-1		75.0	57.0	48.3	64.6	44.2	52.2	51.7	56.1
49a1-27-4		36.2	37.5	35.9	57.2	...	53.2	...	44.0
49a2-2		52.5	65.0	30.9	68.8	...	60.0	...	55.4
49a2-9		55.0	22.5	19.9	60.0	...	54.1	42.5	42.3
49a2-13		67.5	51.2	49.8	64.0	47.0	51.0	...	55.1
49a2-13-1		55.0	55.0	37.8	64.1	...	59.0	...	54.2
49a2-14		47.5	45.0	29.9	63.3	...	64.6	...	50.1
49a2-15		80.0	38.3	38.2	67.7	...	54.9	...	55.8
49a2-16-10		63.7	70.0	40.0	72.9	42.0	48.7	46.8	54.9
49a2-17		55.0	58.7	39.0	65.6	...	55.5	...	54.8
49a2-18		67.5	54.3	40.3	67.1	48.8	55.6	54.7	55.5
49a2-18-2		55.0	68.7	30.6	71.3	...	56.5	...	56.4
49a2-19-5		55.0	67.5	33.7	65.2	...	63.2	51.4	56.0
49a2-20		67.5	46.6	38.5	74.8	48.6	49.3	...	54.2
49a2-20-14		61.2	45.0	...	69.5	...	48.1	...	55.9
49a2-22		67.5	...	55.4	57.6	50.0	49.6	...	56.0
49a2-23-1		60.0	25.0	32.2	57.0	...	55.4	...	45.9
49a2-23-3		50.0	50.0	31.5	60.4	...	51.2	...	48.6
49a2-23-4		56.2	30.0	28.5	61.2	...	44.8	...	44.1
49a2-27		65.0	62.5	35.1	63.2	...	58.4	57.5	56.9

TABLE 2 — (*concluded*)

Pedigree number	Varieties	1907	1908	1909	1910	1911	1912	1913	Average yield
50a1-3	Sixty Day × Probsteier	60.0	60.0	32.6	57.8		59.4		54.0
50a1-3-4		65.0	62.5	37.5	54.1		52.0	.	54.2
50a1-10		80.0	62.5	48.4	60.5	56.1	54.8	59.4	60.2
50a1-13		.		39.4	74.7		56.9	.	57.0
50a1-13-2		60.0	32.5	37.8	44.1		52.6		45.4
50a1-16-1		61.2				.		..	61.2
50a1-16-2		62.5	50.0	35.2	62.7		53.0	. .	52.7
50a1-18		50.0			.	.		. .	50.0
50a1-18-2		62.5	62.5	42.0	57.4		59.5	51.9	56.0
50a1-18-3		55.0	62.5	37.4	46.9		53.8	..	51.1
50a1-20-19		65.0	60.0	32.6	50.7		55.6	...	52.8
50a1-22		75.0	60.0	40.0	62.2	57.1	55.0	54.2	57.6
50a1-24		52.5	65.0	36.5	61.3	.	55.4	....	54.1
50a1-25		55.0	45.0	39.7	59.5	..	57.4	....	51.3
51a1-12	Sixty Day × European Hulless	...	27.5	31.4	45.7		...	....	34.9
51a1-15		.	27.5	21.1	50.5		...	....	33.0
51a2-32		51.2	57.5	33.4	57.4		48.6	....	49.6
33a1-7-3	Selections from Burt	35.0		29.7	80.3		58.6	....	50.9
33a1-7-4		45.0	.	28.6	81.4		56.4	...	52.8
33a1-7-6		40.0	. .	28.8	89.1		55.8	52.3	53.2
33a1-8		40.0		35.3	79.4		53.4	..	52.0
33a1-10-2		41.2		35.7	82.4		56.2	58.0	54.7
33a1-13		40.0	.	.			.	. .	40.0
33a1-14		33.7		35.3	93.4		51.2	51.3	53.0
33a1-15		41.2	58.7	44.2	64.8	47.2	51.4	53.8	51.6
62-II-6-2	Sixty Day selections	63.7	65.0	43.3	59.8	50.2	41.5	46.3	52.8
62-II-6-3		60.0	60.0	43.6	61.5	48.3	42.5	. .	52.6
62-II-17-1		62.5	57.5	42.3	59.4	46.6	42.9	..	51.9
62-II-18-1-1		57.5	67.5	33.4	76.3	53.9	53.2	.	57.0
62-II-18-3			57.5	47.1	71.3	57.4	54.2	47.7	55.9
62-II-19		32.5	.				. .	..	32.5
62-II-19-1		.	65.0	43.1	39.5		48.7	.	49.1
62-II-19-2		70.0		40.7	44.7		55.3	56.4	53.4
62-II-19-3		....	67.5	41.6	42.9		...	...	50.7
63-I-1	Burt (Extra Early) selections	36.2	.	.	.	..	....	....	36.2
63-I-4		42.5	57.5	39.9	62.3	46.2	50.2	52.4	50.1
63-I-5		45.0	.	...		. .	.	....	45.0
63-I-7		55.0	. .	.	68.1	. .	44.5	....	55.9
115-21	Rustproof selection	42.5	30.0	36.3	53.4	36.4	62.6	....	43.5
117-3	Early Champion (Alaska) selections	50.0	20.0	35.0	48.4	41.3	44.2	....	39.8
117-5		52.5	17.5	24.2	45.9	.	39.6	....	35.9
118-7	Silvermine (Musselshell) selection	51.2	47.5	39.9	51.4	.	82.8	66.3	56.5
120-9	Silvermine (Great Dakota) selection	57.5	42.5	48.3	62.7	62.0	67.3	69.5	58.5
123-5	Welcome selection	53.7	67.5	46.8	61.2	64.0	69.8	68.9	61.7
125-3	Silvermine (Great American) selections	32.5	...	...	.	..	....	....	42.5
125-20		52.5	40.0	43.6	56.0	88.4	72.9	68.2	60.2
125-4		57.5	....	...	76.8	....	64.8	66.1	66.3
131-19	Pringle's Progress selection	37.5	40.0	35.7	50.6	54.4	56.5	55.7	47.2
132-2	Sixty Day selection	58.7	60.0	41.9	56.4	43.6	49.1	....	51.6
137-6	Early Champion selections	50.0	32.5	36.9	44.6	43.6	39.2	....	41.1
137-8		50.0	45.0	34.9	36.9	...	34.6	....	40.3
137-21		52.5	..	....	46.9	35.5	37.0	....	43.0
138-1	Early Champion (Prosperity) selections	65.0	40.0	37.6	48.1	37.3	30.4	....	43.1
138-5		57.5	55.0	41.4	48.1	30.6	39.2	....	45.3
142-1	Gold Mine selection	47.5	35.0	34.8	34.8	36.7	39.1	...	38.0
5938-1	Sixty Day selection	60.0	55.0	56.9	57.5	49.5	55.2	55.7	55.7

It is apparent that a number of strains that were grown in 1907 were immediately afterwards eliminated from the test. Most of the strains that were retained from 1907 were tested in 1908, 1909, 1910, and 1912. The actual yields or the average of the yields are given in this table and have not been compared with the checks.

The data given in Table 2 furnish some very interesting facts as to the importance of certain hybrids. These results are shown in Table 3. The average for all the tests of the different series is given.

TABLE 3. YIELDS OF DIFFERENT CLASSES OF HYBRIDS, TAKEN FROM TABLE 2*

Series number	Number of strains tested	Varieties crossed	Yield (bushels per acre)
50	14	Sixty Day × Probsteier	54.2
31	2	Burt (Early White) × Texas Red Rustproof	53.6
49	25	Sixty Day × Clydesdale	52.3
8	7	Clydesdale × Asia Minor Rustproof (3676)	52.1
27	2	Garton's Tartar King × Clydesdale	51.3
42	3	Asia Minor Rustproof (3676) × Clydesdale	51.1
34	33	Burt (Early White) × Sixty Day	50.6
30	4	Burt (Early White) × Clydesdale	50.4
32	1	Burt (Early White) × Early Champion	49.6
3	3	Golden Giant × Asia Minor Rustproof (3676)	46.3
33	9	Burt (Early White) × Burt (Extra Early)	45.3
51	3	Sixty Day × European Hulless	41.1

* These results are taken from the yields for the different years, not from the column of averages.

It is seen from this table that the series ranking highest is No. 50, Sixty Day × Probsteier. This series had fourteen strains under test. The next highest series with a large number of strains is No. 49, Sixty Day × Clydesdale. It is rather significant that these two series should have the Sixty Day oat as one parent. The data for these series would be more conclusive if each strain had been tested every year for the seven years; but, since this was not done, the data certainly indicate that for the conditions under which the oats were grown these combinations are better adapted to this particular environment than are the others that were tested.

COMPARISON OF YIELDS OF HYBRIDS AND SELECTIONS

Another interesting point in connection with the data in Table 2 is the comparison of the yields obtained from the hybrids with the yields obtained from the selections.

The yield obtained from all the hybrids tested in 1907 was 50 bushels

an acre, while the yield for all selections was 49.4 bushels an acre. In 1908 the yield for all hybrids was 55 bushels an acre, while that for all selections was 49.3 bushels. The yield for the hybrids in 1909 was 36.5 bushels an acre, while the yield for the selections was 38.9 bushels. For 1910 the yield obtained from the hybrids was 64.6 bushels an acre, while the yield for the selections was 59.9 bushels. The yield for all hybrids in 1911 was 45.9 bushels an acre, while that for all selections was 48.7 bushels. The yield obtained for the hybrids in 1912 was 51.2 bushels an acre, while that for all selections was 51.5 bushels. The yield of all hybrids in 1913 was 52.8 bushels an acre, while that for all selections was 57.9 bushels. The average for all hybrids tested in the years 1907 to 1913 inclusive was 51.2 bushels an acre, while that for all selections tested in the same years was 50.5 bushels. These figures show little difference so far as hybrids and selections are concerned. When the results are taken year by year it is seen that for the years 1909, 1911, 1912, and 1913 the yield of the selections was greater than the yield of the hybrids.

The results, although indicating a slightly higher yield for the hybrids, do not show enough difference for these particular data to warrant recommending hybridization as a means of improvement over selection, at least in a practical way. One of the important reasons for this is that it is possible to handle many selections while one is purifying certain hybrids from one cross. The hybrids must be continued at least to the third generation, and in the meantime many selections can be tested.

It is interesting to compare the yields obtained from the best ten hybrids and selections each year. These results are given in Table 4. For the years 1909 to 1913, only those hybrids and selections are given which were repeated a number of times.

The average yield for the best ten hybrids in 1907 was 71.5 bushels an acre, while the yield for the selections was 61.2 bushels an acre. Among the hybrids are represented only three series: 34 (Burt × Sixty Day), one strain; 49 (Sixty Day × Clydesdale), six strains; and 50 (Sixty Day × Probsteier), three strains. Among the selections are seven strains from Sixty Day, one from Early Champion, and two from Silvermine. These yields indicate that for 1907 a strain similar to the Sixty Day type would give the best yield, for all the hybrids had Sixty Day as one parent.

The average yield of the best ten hybrids in 1908 was 82.2 bushels an acre, while the average yield for the best ten selections was 62.5 bushels. Among the hybrids are seven strains from series 34 (Burt × Sixty Day), and the Sixty Day type predominates among the selections. The earlier strains seemed better adapted to the climatic conditions of 1908.

TABLE 4. YIELDS OF THE BEST TEN HYBRIDS AND THE BEST TEN SELECTIONS FOR EACH YEAR FROM 1907 TO 1913

1907		1908		1909		1910		1911		1912		1913	
Pedigree number	Average yield (bushels per acre)	Pedigree number	Average yield (bushels per acre)	Pedigree number	Average yield (bushels per acre)	Pedigree number	Average yield (bushels per acre)	Pedigree number	Average yield (bushels per acre)	Pedigree number	Average yield (bushels per acre)	Pedigree number	Average yield (bushels per acre)
Hybrids													
50a1-10	80.0	34a1-28-2	95.0	49a2-22	55.4	34a1-11-2	75.0	34a1-11-2	58.1	27a1-31	64.9	27a1-31	67.8
49a2-15	80.0	34a1-19-1	90.0	34a1-11-2	53.2	49a2-20	74.8	50a1-22	57.1	50a1-18-2	59.5	34a1-11-2	61.8
49a1-27-1	75.0	34a1-11-2	85.0	34a1-24	50.6	49a2-16-10	72.9	50a1-10	56.1	49a2-27	58.4	30a2-12-3	60.4
50a1-22	75.0	34a1-32-1	85.0	31a1-16-1	50.1	49a2-18-2	71.3	27a1-31	50.8	34a1-11-2	57.3	50a1-10	59.4
50a1-18-4	70.0	31a1-16-1	82.5	49a2-13	49.8	34a1-28-2	70.6	49a2-22	50.0	50a1-13	56.9	49a2-27	57.5
49a2-22	67.5	34a1-13-5	80.0	34a1-27-3	48.7	27a1-31	69.8	49a2-18	48.8	33a2-9-2	56.7	8a2-6-1	56.9
49a2-20	67.5	42a1-1-2	80.0	50a1-10	48.4	34a1-32-1	68.1	49a2-20	48.6	49a2-18-2	56.5	38a1-9	54.9
49a2-18	67.5	34a1-21	75.0	49a1-27-1	48.3	49a2-18	67.1	49a2-13	47.0	49a2-18	55.6	49a2-18	54.7
49a2-13	67.5	34a1-18-3	75.0	34a1-27-2	47.0	31a1-16-1	64.7	30a2-12-3	43.8	49a2-17	55.5	33a2-9-2	51.2
34a1-27-3	65.0	31a1-16	75.0	42a1-1-2	44.8	32a2-1	64.7	30a3-33	43.8	50a1-22	55.0	50a1-22	54.2
Average	71.5		82.2		49.6		69.9		50.4		57.6		58.2
Selections													
62-II-19-2	70.0	62-II-18-1-1	67.5	5938-1	56.9	62-II-18-1-1	76.3	123-5	64.0	125-20	72.9	120-9	69.5
138-1	65.0	62-II-19-3	67.5	120-9	48.3	62-II-18-3	71.3	120-9	62.0	123-5	69.8	123-5	68.9
62-II-6-2	63.7	123-5	67.5	62-II-18-3	47.1	33a1-15	64.8	62-II-18-3	57.4	120-9	67.3	125-20	68.2
62-II-17-1	62.5	62-II-6-2	65.0	123-5	46.8	120-9	62.7	62-II-18-1-1	53.9	125-4	64.8	118-7	66.3
62-II-6-3	60.0	62-II-19-1	65.0	62-II-6-3	43.6	63-I-4	62.3	62-II-6-2	50.2	62-II-19-2	55.3	125-4	66.1
5938-1	60.0	62-II-6-3	60.0	62-II-6-2	43.3	62-II-6-3	61.5	5938-1	49.5	5938-1	55.2	33a1-10-2	58.0
132-2	58.7	132-2	60.0	62-II-19-1	43.1	123-5	61.2	62-II-6-3	48.3	62-II-18-3	54.2	62-II-19-2	56.4
62-II-18-1-1	57.5	62-II-17-1	57.5	62-II-17-1	42.3	62-II-6-2	59.8	33a1-15	47.2	62-II-18-1-1	53.2	131-19	55.7
120-9	57.5	62-II-18-3	57.5	132-2	41.9	62-II-17-1	59.4	62-II-17-1	46.6	33a1-15	51.4	5938-1	55.7
125-4	57.5	63-I-4	57.5	138-5	41.4	5938-1	57.5	63-I-4	46.2	33a1-14	51.2	33a1-15	53.8
Average	61.2		62.5		45.5		63.7		52.5		59.5		61.9

For 1909 the average yield of the best ten hybrids was 49.6 bushels an acre, while that for the best ten selections was 45.5 bushels. This year series 49 (Sixty Day × Clydesdale) furnished the best hybrid, while the best selection was a strain from Sixty Day — in fact, seven of the selections are from Sixty Day and one is from Early Champion.

In 1910 the average yield for the best ten hybrids was 69.9 bushels an acre, while that for the best ten selections was 63.7 bushels. The best yield was obtained from a selection, however. This is a Sixty Day strain. The next best yield is from a Burt × Sixty Day hybrid. The early strains seem to be best for 1910.

The average yield for the best ten hybrids in 1911 was 50.4 bushels an acre, while that for the best ten selections was 52.5 bushels. The best yields are obtained from two selections, 123–5 (Welcome), yielding 64 bushels, and 120–9 (Silvermine), yielding 62 bushels. The best hybrid is the Burt × Sixty Day strain that was highest in 1910.

In 1912 the best ten hybrids gave an average yield of 57.6 bushels an acre, while the best ten selections averaged 59.5 bushels. The best yields were obtained by selections. Two of these, 125–20 and 120–9, are Silvermine selections, while 123–5 is a Welcome selection. The best hybrid strain is one from a cross of Garton's Tartar King × Clydesdale.

The average yield of the best ten hybrids in 1913 was 58.2 bushels an acre, while that for the best ten selections was 61.9 bushels. The selections again gave the best yields. Silvermine selections 120–9 and 125–20, and Welcome selection 123–5, gave the best yields, while the next best yield was obtained from 27a1–31, Garton's Tartar King × Clydesdale.

This table shows the constancy of certain hybrids and selections. For example, the Burt × Sixty Day hybrid 34a1–11–2 ranked third in 1908, second in 1909, first in 1910 and 1911, fourth in 1912, and second in 1913. The Garton's Tartar King × Clydesdale hybrid 27a1–31 did not give good yields until the last few years, when the later-maturing varieties did the best. This strain ranked sixth among the hybrids in 1910, fourth in 1911, and first in 1912 and 1913.

Among the selections one does not find a strain giving the best yields as regularly as did the Burt × Sixty Day hybrid. Welcome selection 123–5, however, was among the best three selections in 1908, ranked fourth in 1909, seventh in 1910, first in 1911, and second in 1912 and 1913. Silvermine selection 120–9 ranked second in 1909, fourth in 1910, second in 1911, third in 1912, and first in 1913. These two strains have yielded very close together, as the average for 120–9 is 62 bushels an acre and that for 123–5 is 62.1 bushels for the years 1909 to 1913. In other words,

they yield exactly the same, since the experimental error will take care of any such small differences as one tenth or two tenths of a bushel, or even a bushel or two.

PLACE VARIATION

It is evident from the foregoing data that there is considerable variation in results from year to year. This is emphasized by the yields of the best ten hybrids and the best ten selections for each year. In certain years the earlier strains, represented by the Burt or the Sixty Day type, give the best yields, while in other years the later types, represented by Silvermine or Welcome, give the best yields. This place variation operates to make one-year variety tests inconclusive. Unusual conditions affecting the results may arise in any season. For example, the seasons of 1909 and 1910 were very similar, being rather hot and dry at the time when the oats were filling and ripening. Such conditions favor the Sixty Day type, since that type will withstand more hot, dry weather than the later-growing sorts. The seasons of 1911 and 1912, while much alike, were very different from those of 1909 and 1910. These seasons were hot and dry at the time when the earlier sorts of oats were maturing. Most of the hybrids and selections maturing early ripened under adverse conditions. Before the later-maturing strains were ripe, however, rain and cooler weather came on, which allowed these strains to ripen under more favorable conditions. The usual conditions being reversed in this way, an advantage resulted for the later-maturing varieties. This is evidenced by the fact that the best-yielding strains for 1909 and 1910 were early types, represented by the Sixty Day series, while the best-yielding strains for 1911 and 1912 were later types, represented by the Silvermine series.

It seems evident from these data that variety tests of one year, or even of two years, are too short, and that the tests must be continued through several years.

More information on this point is obtained from Table 5, which shows the results for all the strains that have been tested every year for the six years from 1907 to 1912. This table is arranged in order according to the average yield for the entire test, the highest average being given first.

The strain that gives the highest average yield for the six years is 34a1–11–2 (Burt × Sixty Day). If, however, a selection of only one strain had been made from the results of 1911 and 1912, this strain would not have been selected, since several other strains outyielded it. The second best yield was obtained from Welcome selection 123–5. If only one strain had been selected from the 1909 and 1910 tests this strain

would not have been saved, since it was outyielded by some other strain.

TABLE 5. YIELDS IN BUSHELS PER ACRE OF HYBRIDS AND SELECTIONS TESTED EACH YEAR FROM 1907 TO 1912 INCLUSIVE

Rank	Pedigree number	1907	1908	1909	1910	1911	1912	Average for six years
1	34a1-11-2	37 5	85 0	53 2	75 0	58.1	57 3	61 0
2	123-5	53 7	67 5	46 8	61 2	64 0	69 8	60 5
3	50a1-10	80 0	62 5	48 4	60 5	56 1	54 8	60 4
4	125-20	52 5	40 0	43 6	56 0	88 4	72 9	58 9
5	50a1-22	75 0	60 0	40 0	62 2	57 1	55 0	58 2
6	62-II-18-1-1	57 5	67 5	33 4	76 3	53 9	53.2	57 0
7	49a1-27-1	75 0	57 0	48 3	64 6	44 2	52 2	56 9
8	34a1-28-2	50 0	95 0	38 7	70 6	43 3	43 3	56 8
9	120-9	57 5	42 5	48 3	62 7	62.0	67 3	56 7
10	49a2-16-10	63 7	70 0	40 0	72 9	42 0	48 7	56.2
11	34a1-32-1	57 5	85 0	40 9	68 1	43 9	40 5	56.0
12	5938-1	60 0	55 0	56 9	57 5	49 5	55 2	55.7
13	34a1-27-3	65 0	63 7	48 7	64 0	42 3	49.7	55.6
14	49a2-18	67 5	54 3	40 3	67 1	48 8	55 6	55.6
15	34a1-24	63 7	70 0	50 6	62 5	42 1	43 7	55.4
16	31a1-16-1	46 2	82 5	50 1	64 7	40 2	47.2	55.1
17	49a2-13	67 5	51 2	49 8	64.0	47 0	51.0	55.1
18	34a1-27-2	58 7	69 1	47 0	60 3	43 6	49 1	54.6
19	49a2-20	67.5	46 6	38 5	74.8	48 6	49 3	54.2
20	62-II-6-2	63.7	65 0	43 3	59 8	50.2	41.5	53.9
21	42a1-1-2	46.9	80 0	44.8	59 0	42 1	49 0	53.6
22	27a1-31	45.0	43 3	47 5	69 8	50 8	64.9	53.5
23	62-II-6-3	60 0	60.0	43 6	61.5	48.3	42.5	52.6
24	30a2-12-3	58 7	61.2	34 6	63 5	43.8	51.2	52.2
25	62-II-17-1	62 5	57 5	42.3	59 4	46 6	42 9	51 9
26	132-2	58.7	60.0	41 9	56 4	43.6	49 1	51.6
27	33a1-15	41.2	58.7	44.2	64 8	47.2	51.4	51 2
28	32a2-1	42.5	62 5	42 8	64.7	39.3	47.2	49.8
29	63-I-4	42.5	57.5	39 9	62 3	46 2	50 2	49.8
30	30a3-33	57.5	37.5	37 8	66 5	43.8	50 5	48.9
31	131-19	37.5	40 0	35.7	50 6	54 4	56.5	45 8
32	142-1	47.5	35.0	34.8	34 8	36 7	39.1	38 0

This place variation is also well illustrated by figures 33 and 34. The solid-line curve in Fig. 33 represents graphically the yields for the different series in the year 1910, as given in Table 5, while the dotted line represents the yields for the same strains in 1911. These curves are plotted in the order of the series numbers as they appear in Table 5. As stated above, these seasons were very different, and there is little agreement between the two curves. The solid line in Fig. 34 represents the yield for the strains in 1911 and the dotted line represents the yield for the same strains in 1912. These seasons were similar, and a closer agreement of the curves is seen.

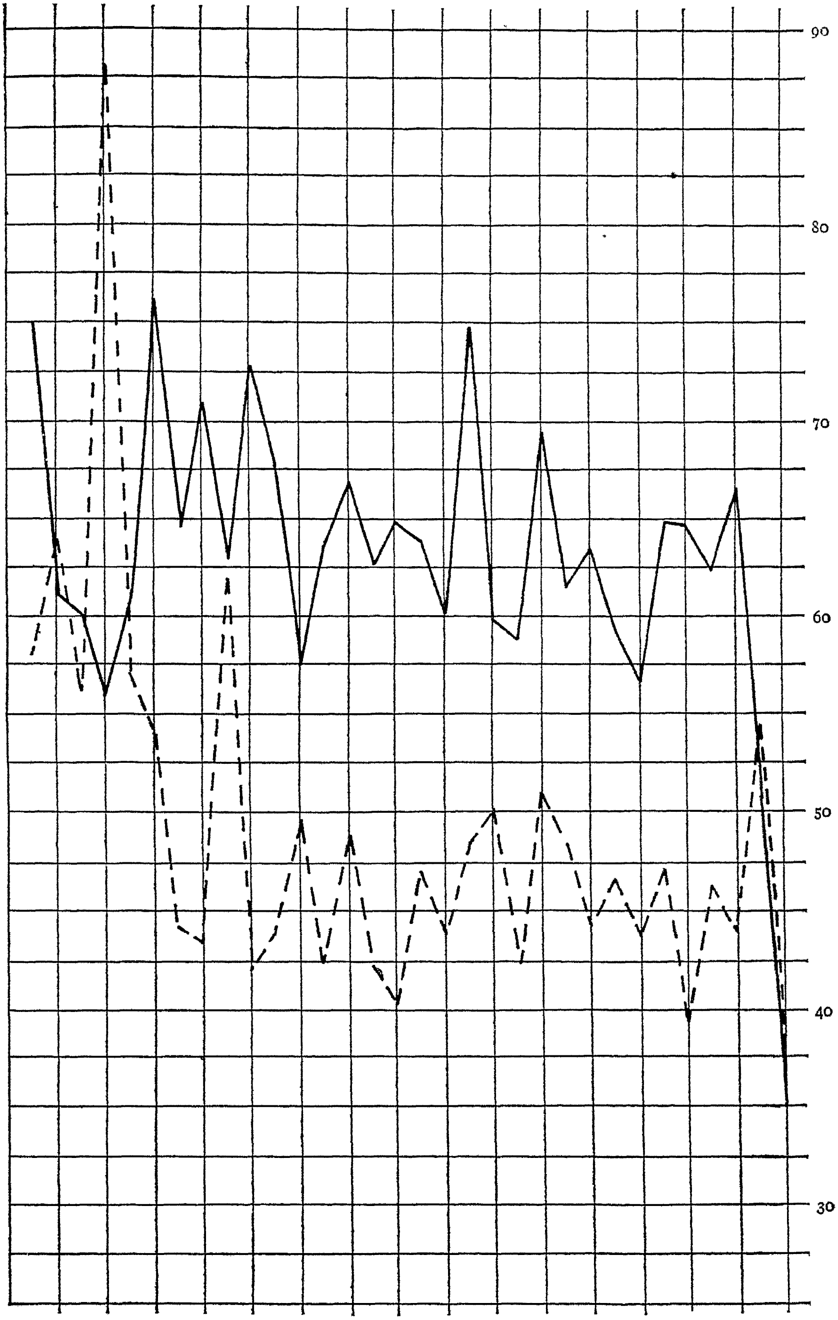

FIG. 33.— *Variation of yield in bushels per acre of certain hybrids and selections that were tested in 1910 and 1911. The curves do not correspond closely. The seasons were very different*

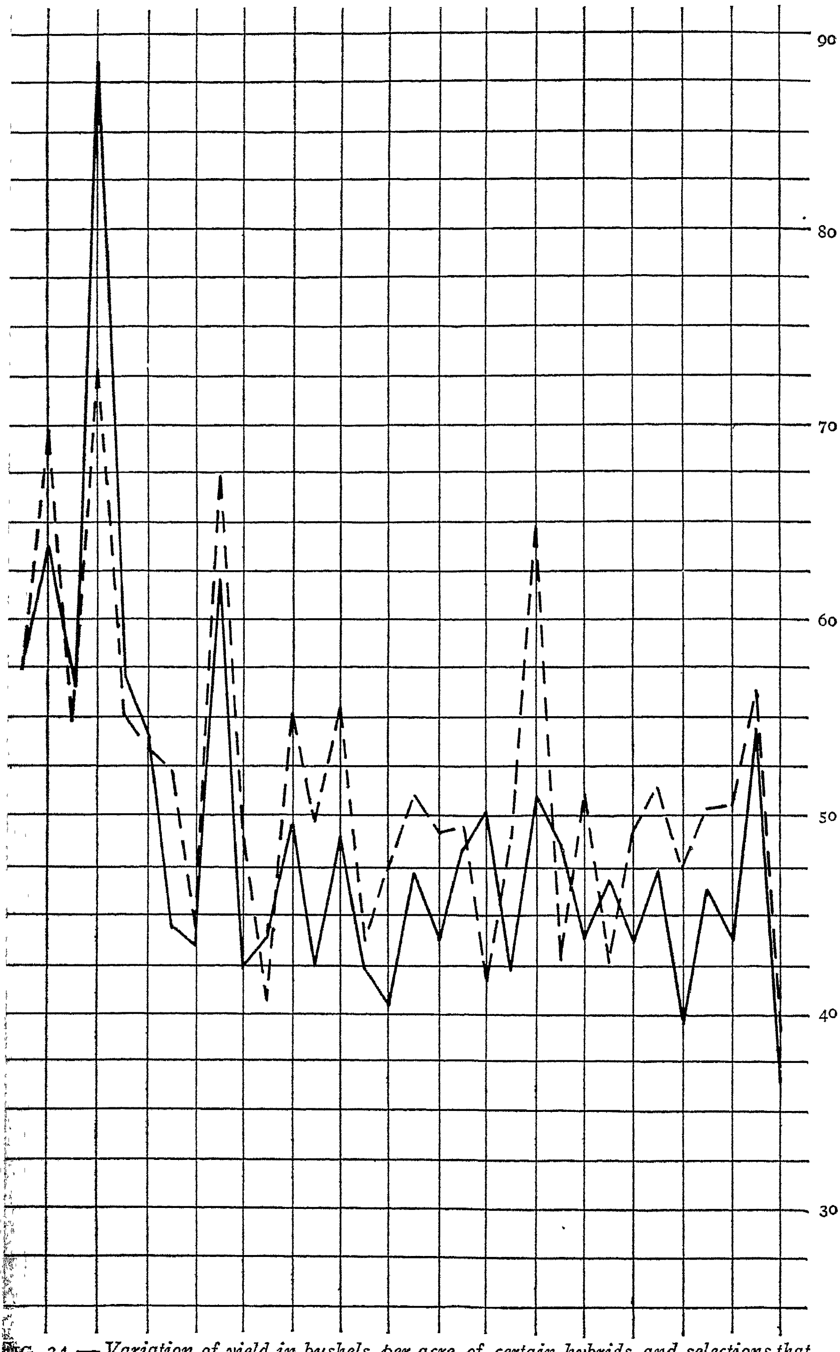

FIG. 34.—*Variation of yield in bushels per acre of certain hybrids and selections that were tested in 1911 and 1912. Note the similarity between the curves. The seasons were similar*

The yields of the hybrids and the selections that have been grown every year for the seven years are shown in Table 6. The series are arranged in order of yield, beginning with the highest.

TABLE 6. YIELDS IN BUSHELS PER ACRE OF HYBRIDS AND SELECTIONS TESTED EACH YEAR FROM 1907 TO 1913 INCLUSIVE

Rank	Pedigree number	1907	1908	1909	1910	1911	1912	1913	Average for seven years
1	123–5	53.7	67.5	46.8	61.2	64.0	69.8	68.9	61.7
2	34a1–11–2	37.5	85.0	53.2	75.0	58.1	57.3	61.8	61.1
3	50a1–10	80.0	62.5	48.4	60.5	56.1	54.8	59.4	60.2
4	125–20	52.5	40.0	43.6	56.0	88.4	72.9	68.2	60.2
5	120–9	57.5	42.5	48.3	62.7	62.0	67.3	69.5	58.5
6	50a1–22	75.0	60.0	40.0	62.2	57.1	55.0	54.2	57.6
7	49a1–27–1	75.0	57.0	48.3	64.6	44.2	52.2	51.7	56.1
8	5938–1	60.0	55.0	56.9	57.5	49.5	55.2	55.7	55.7
9	27a1–31	45.0	43.3	47.5	69.8	50.8	64.9	67.8	55.6
10	49a2–18	67.5	54.3	40.3	67.1	48.8	55.6	54.7	55.5
11	34a1–28–2	50.0	95.0	38.7	70.6	43.3	43.3	46.0	55.3
12	49a2–16–10	63.7	70.0	40.0	72.9	42.0	48.7	46.8	54.9
13	34a1–27–3	65.0	63.7	48.7	64.0	42.3	49.7	50.9	54.9
14	31a1–16–1	46.2	82.5	50.1	64.7	40.2	47.2	53.2	54.9
15	34a1–24	63.7	70.0	50.6	62.5	42.1	43.7	50.8	54.8
16	30a2–12–3	58.7	61.2	34.6	63.5	43.8	51.2	60.4	53.3
17	62–II–6–2	63.7	65.0	43.3	59.8	50.2	41.5	46.3	52.8
18	42a1–1–2	46.9	80.0	44.8	59.0	42.1	49.0	47.2	52.7
19	33a1–15	41.2	58.7	44.2	64.8	47.2	51.4	53.8	51.6
20	63–I–4	42.5	57.5	39.9	62.3	46.2	50.2	52.4	50.1
21	32a2–1	42.5	62.5	42.8	64.7	39.3	47.2	48.4	49.6
22	131–19	37.5	40.0	35.7	50.6	54.4	56.5	55.7	47.2

It is seen that the strains ranking first and second in Table 5 have exchanged places in Table 6. It is seen also that the results for the last three years, 1911, 1912, and 1913, have been very similar. The varieties yield either high or low for the three seasons. The seasons have not been similar as to amount of rainfall, temperature, and the like, but the three years as a whole were more favorable to medium or late oats than they were to the earlier strains. The close agreement between the yields for the three years is well brought out by Fig. 35, which illustrates the yields for the last three years as given in Table 6, arranged according to the rank of the varieties as shown in Table 5.

TRANSMISSION OF HIGH YIELD

By an examination of the various foregoing tables it is evident that many of the strains under test are not constantly high-yielding. There are some strains, however, which are always among the best in yield. Considering the results for the years 1909 to 1913,[5] it is evident that for the selections such strains as Welcome selection 123–5 and Silvermine

[5] This period is taken since the different strains were repeated several times in the test each year.

selection 120–9 are always to be found ranking with the best in yield. Among the hybrids there are none that always rank high. Certain ones, however, especially from series 34 and 50, average well for all tests. Welcome selection 123–5 gives the highest average for all the strains tested.

For seasons similar to those of 1911, 1912, and 1913 in central New York, some of the later strains yield much better than do the earlier types.

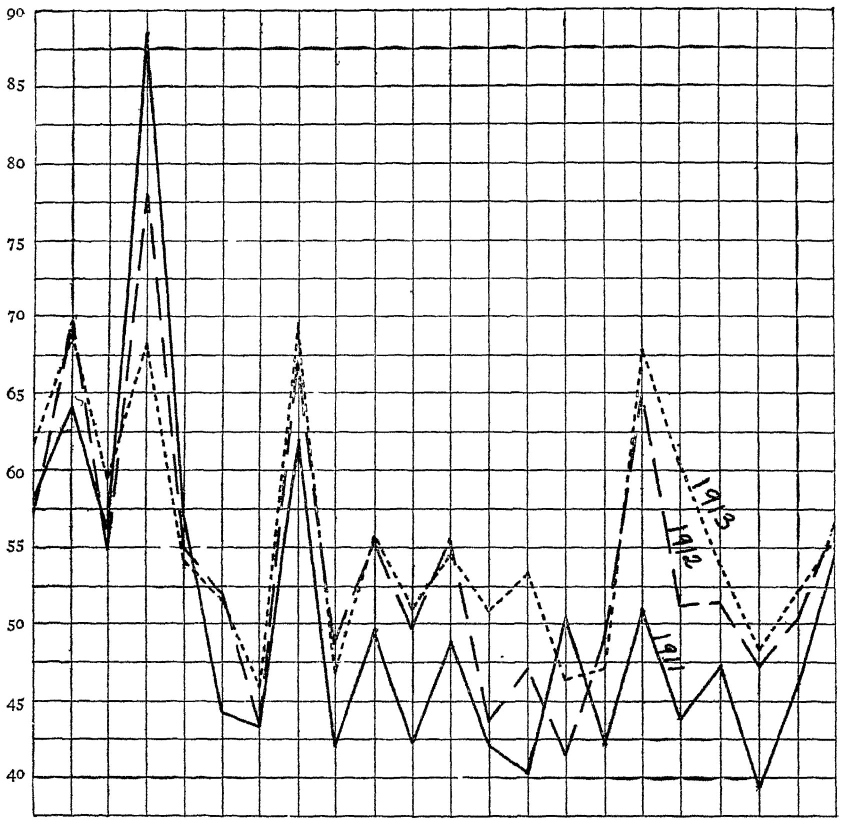

FIG. 35.— *Yields of some hybrids and selections of oats for 1911, 1912, and 1913, arranged according to the rank of these varieties as shown in Table 5*

For example, the Welcome and Silvermine selections yielded much better in those years, while during the earlier years of the work such strains as Sixty Day selection and the Burt × Sixty Day hybrid 34a1–11–2 were the best in yield. Since the seasons of 1911 and 1912 were different from the seasons of earlier years, the later types have given better results; so that for the complete series of tests we find a Welcome selection, a Burt

× Sixty Day cross, and a Sixty Day × Probsteier cross heading the list. When the seasons are similar there is evidence of transmission of high yield, as is brought out by Fig. 34. For example, 123–5 yielded high in both years, as did also 120–9. The hybrid 34a1–11–2 also yielded about the same in each year. It may be pointed out in addition that 142–1 yielded extremely low in both seasons.

The influence of place variation is so great that the question of transmission of high yield is difficult to settle when tests have been conducted for only a short period of time. The real test for a strain or a variety is whether it gives a high average through a series of years. The strain that occasionally gives an extremely high yield and then a very medium yield for several years is not a desirable type. The hybrids 34a1–11–2 and 50a1–10, and the selection 123–5, are found to average well, although they are not the highest in yield year by year.

TESTS OF SOME COMMERCIAL VARIETIES IN COMPARISON WITH SOME OF THE BEST STRAINS

A number of commercial varieties were grown in 1911 and more were added in 1912 and 1913. These varieties were bought from different seedsmen with the intention of obtaining both early and late sorts. Some varieties were also obtained from some of the experiment stations in this country and Canada. So far as possible all the more common varieties were included, so that definite information could be gained as to the varieties that are being grown in New York State.

The commercial oats were tested in the same manner that the hybrids and selections were, that is, by the rod-row system.

The yields of those varieties that have been tested for the three years 1911 to 1913 are given in Table 7. A few of the better-yielding hybrids and selections are also given.

From the results shown in this table it is seen that Silvermine, Great American — which is a Silvermine type — Twentieth Century, and Welcome selection 123–5 are close together for the three-years average. There is a difference of only 1.8 bushel between the highest and the lowest average for these four. This difference is easily accounted for by the experimental error, which is referred to on page 374. Following these strains are Lincoln, Silvermine selection 120–9, and Silvermine 21385. It is clear from the results shown here that a strain of the Silvermine type is the best for the conditions under which these oats were grown.

The selection 123–5 is being distributed for further testing in different parts of the State and has yielded very well in many localities. It has not yielded higher than the Silvermine, but the difference is so small that the two varieties may be said to yield about the same, especially

since, as already stated, the experimental error will account for the difference. The Department of Plant-breeding at this College is recommending Welcome selection 123–5 for a number of localities, since pure seed of this sort is in its possession. One cannot be sure of always obtaining pure varieties on the open market, especially since different varieties are sold under the same name and again the same variety under different names. With this in mind, seed of this selection and of one or two others is being distributed.

TABLE 7. YIELD OF THE COMMERCIAL VARIETIES, TOGETHER WITH SOME OF THE HYBRIDS AND SELECTIONS GROWN, 1911, 1912, AND 1913

Variety	1911	1912	1913	Average
Silvermine P. B. 1571	70.7	66.3	71.3	69.4
Great American	66.2	69.3	68.0	67.8
Twentieth Century	64.7	70.8	67.6	67.7
123–5	64.0	69.8	68.9	67.6
Lincoln	58.9	70.4	70.2	66.5
120–9	62.0	67.3	69.5	66.3
Silvermine S. P. I. 21385	64.8	60.9	66.5	64.1
Danish Island	53.8	64.8	66.8	61.8
27a1–31	50.8	64.9	67.8	61.2
Long's White Tartar	51.3	62.3	68.0	60.5
34a1–11–2	58.1	57.3	61.8	59.1
Swedish Select P. B. 1575	47.8	61.7	56.6	55.4
5938–1	49.5	55.2	55.7	53.5
Swedish Select P. B. 2036	45.5	55.9	58.2	53.2
Welcome	41.5	56.5	57.5	51.8
Black Tartarian	45.8	52.0	55.9	51.2
White Tartar King	38.0	52.3	59.9	50.1
Golden Giant Side	47.1	47.8	48.3	47.7
Sixty Day	46.2	41.7	47.5	45.1
Early New Market	36.1	44.8	53.7	44.9
Early Champion	46.0	39.7	42.5	42.7
Red Texas	30.6	37.7	50.9	39.7

The different lots of Silvermine and Great American were grown in order to test the difference between the seed from different localities. The same is true of the Swedish Select. There is an average difference of 5.3 bushels between the two lots of Silvermine seed, while the Great American ranks close to Silvermine 1571. One of these lots of Silvermine seed, S. P. I. 21385, is an importation, while the other, P. B. 1571, was obtained from Illinois. There was really no difference between the two lots of Swedish Select.

It is well to note how inferior Swedish Select is to the Silvermine, Twentieth Century, Welcome selection, and Lincoln strains. It is not an oat that does well when grown under such conditions as these varieties

were grown under. Early New Market is another variety that has not done well. This is a large-kerneled oat, which produces large, heavy straw; but owing to the dry weather it does not fill out well, therefore it gives a very low yield of grain to the acre.

It is well to note also that the very early oats, such as Early Champion and Sixty Day, gave poor yields in the tests. It is well to mention, however, that in some parts of the State certain selections of Sixty Day produced more grain than some of the latter sorts. There are localities, no doubt, especially in southern New York, where the Sixty Day oat may outyield any other varieties. It matures early enough to escape much of the hot weather and drought under which New York oats are required to fill and ripen. Red Texas, which is also grown as a winter oat in the South, gives a poor yield when grown as a spring oat in New York.

The table brings out also the importance of selection and emphasizes the possibility of improvement of oats by selection. For example, the yield of the Welcome variety may be compared with the yield of the selection from this variety. The variety gave an average yield for the three years of 51.8 bushels an acre, while Welcome selection 123–5 gave an average yield of 67.6 bushels for the same period. This is a gain of 15.8 bushels an acre. The Sixty Day variety gave a yield of 45.1 bushels an acre for the three years, while 5938–1, which is a selection from Sixty Day, yielded 53.5 bushels; a difference of 8.4 bushels an acre in favor of the selection.

Silvermine selection 120–9, however, did not show a gain when compared with the seed from Illinois, while compared with Silvermine 21385 there is a gain of 2.2 bushels. The average of the two Silvermine varieties is 66.7, while the average for the selection is 66.3. Thus it is that some selections fail to show any pronounced gain over the varieties, and this fact emphasizes the importance of selecting large numbers when any improvement work is to be undertaken.

As before stated, a large number of varieties were added in 1912 and more in 1913. The varieties, together with the hybrids and the selections that have been tested for the past two years, are shown in Table 8 and graphically in Fig. 36. In the table the actual yields — the average of all the tests for each variety —for the two years are shown, together with the gain or the loss over the check variety for each year and the average gain or loss for the two years.

This comparison has been made in the following manner: As stated under the discussion of methods of work, every tenth row is sown with the same kind of seed as a check. In order to determine what is the check yield for any part of the field, the difference between the nearest checks is obtained and divided into tenths, since there are checks in every tenth

s then graded by tenths, either subtracting from or
st check. For example, it may be supposed that the
10 is 50 bushels and that for check row 20 is 60 bushels.
bushels, and it is assumed that the soil is gradually
y; therefore the difference divided by 10 is added
ck 10 in order to find the theoretical check yield at
tical checks between rows 10 and 20 would thus be:

	Theoretical check yield
....	50
....	51
....	52
....	53
....	54
....	55
....	56
....	57
....	58
....	59
....	60

theoretical checks for any row in any part of the field

of comparing the different varieties as is here done,
ecks for each of ten tests (each variety being repeated
n determined, then the theoretical checks have been
pared with the strains tested; that is, the calculated
ave been obtained from the average of the ten checks
The same variety was used for the check each year,
es above or below the check are comparable for the

ALL VARIETIES AND STRAINS TESTED FOR THE YEARS 1912
ETHER WITH GAIN OR LOSS OVER THE CHECK VARIETY*

ty	Yield in bushels		Gain or loss over check		Average
	1912	1913	1912	1913	
King × Clydesdale.	64.9	62 4	+ 5.4	+ 0.6	+ 3.0
....	70.4	70.2	+11.3	+ 8.6	+ 9.9
....	52.3	59.9	— 6.2	— 1.4	— 3 8
White) × Clydesdale.	51.2	60.4	— 6 9	— 0 6	— 3 7
....	64.8	66.8	+ 7.0	+ 6 0	+ 6.5

cording to the plan of planting, rather than in the order of the gain over check.

8a2-6-1 Clydesda
(3676)
Morgan Feller P.
Gold Mine P. B.
33a1-14 Burt sel
White Plume P. 1
33a2-9-2 Burt (1
Early). ....
Black Anthony
34a1-13-5 Burt
Sensation P. B.
President P. B.
34a1-32 Burt (E
Victory P. B. 17
49a1-25 Sixty 1
White Bonanza
Fourth of July
Joanette P. B.
Seizure P. B. 17
New White Clu
49a2-27 Sixty 1
Golden Fleece 1
Silver White M
50a1-18-2 Sixty
Winter P. B. 64
125-4 Silvermine
Garton 1174 P.
Garton 611 P. 1
Garton 855 P. 1
Avena Sativa D
Tartar King 21
Avena Sativa 2
Red Texas P. B
131-19 Pringle's
Alaska P. B. 17
Bland's White
Early Mountain
Michigan Wond
Progress P. B.
National P. B.
Scotch P. B. 17
Sparrowbill P.
New Danish W
Czar of Russia
Beardless Probs
62-II-19-2 Sixt
Siberian.. ....
S. P. I. 32280..
Canada Cluster

*New seed was

TABLE 8 — (continued)

Variety	Yield in bushels		Gain or loss over check		Average
	1912	1913	1912	1913	
Welcome	56.5	57.5	— 0.7	— 3.0	— 1.8
31a1–16–1 Burt (Early White) × Texas Red Rustproof	47.2	53.2	— 9.6	— 7.1	— 8.3
Silvermine P. B. 1571	66.3	71.3	+ 9.5	+11.3	+10.4
32a2–1 Burt (Early White) × Early Champion	47.2	48.4	— 9.8	—11.4	—10.6
Silvermine S. P. I. 21385	60.9	66.5	+ 3.6	+ 6.6	+ 5.1
33a1–15 Burt (Early White) × Burt (Extra Early)	51.4	53.8	— 6.1	— 6.5	— 6.3
Long's White Tartar P. B. 1568	62.3	68.0	+ 4.5	+ 7.4	+ 5.9
34a1–11–2 Burt (Early White) × Sixty Day	57.3	61.8	— 0.8	+ 0.8	0.0
Swedish Select P. B. 1575	61.7	56.6	+ 3.4	— 4.8	— 0.7
34a1–24 Burt (Early White) × Sixty Day	43.7	50.8	—14.9	—11.0	—12.9
Great American P. B. 1573	69.3	68.0	+10.5	+ 5.8	+ 8.1
Twentieth Century	70.8	67.6	+11.8	+ 5.1	+ 8.4
34a1–27–3 Burt (Early White) × Sixty Day	49.7	50.9	— 9.2	—12.0	—10.6
Clydesdale P. B. 640	57.8	53.4	— 1.1	— 9.8	— 5.4
34a1–28–2 Burt (Early White) × Sixty Day	43.3	46.0	—15.5	—17.0	—16.2
Storm King S. P. I. 21387	52.4	51.9	— 6.4	—11.0	— 8.7
Great Northern S. P. I. 21389	71.0	73.9	+12.3	+11.1	+11.7
42a1–1–2 Asia Minor Rustproof (3676) × Clydesdale	49.0	47.2	— 9.6	—15.4	—12.5
Ligowo White S. P. I. 21390	56.5	53.8	— 2.0	— 8.7	— 5.3
49a1–27–1 Sixty Day × Clydesdale	52.2	51.7	— 6.1	—10.7	— 8.4
Goldfinder S. P. I. 21391	56.3	53.5	— 1.9	— 8.8	— 5.3
Abundance S. P. I. 21392	53.9	55.3	— 4.0	— 6.8	— 5.4
49a2–16–10 Sixty Day × Clydesdale	48.7	46.8	— 9.1	—15.1	—12.1
Big Four S. P. I. 21386	54.7	60.5	— 3.0	— 1.2	— 2.1
49a2–18 Sixty Day × Clydesdale	55.6	54.7	— 2.0	— 6.9	— 4.4
Colossal S. P. I. 21393	46.4	55.3	—11.0	— 6.1	— 8.5
White Russian	50.0	57.4	— 7.5	— 3.9	— 5.7
Early New Market P. B. 1569	44.8	53.7	—12.9	— 7.5	—10.2
50a1–10 Sixty Day × Probsteier	54.8	59.4	— 3.0	— 1.6	— 2.3
Mortgage Lifter P. B. 638	49.0	62.3	— 8.9	+ 1.4	— 3.7
50a1–22 Sixty Day × Probsteier	55.0	54.2	— 3.0	— 6.5	— 4.7
Kherson P. B. 644	46.4	55.5	—11.7	— 5.1	— 8.4
62–II–6–2 Sixty Day selection	41.5	46.3	—16.7	—14.4	—15.5
Golden Wonder P. B. 647	64.9	70.2	+ 6.6	+ 9.5	+ 8.0
Green Mountain P. B. 658	64.3	67.3	+ 6.0	+ 6.6	+ 6.3
Golden Giant Side	47.8	48.3	—10.4	—12.4	—11.4
Sixty Day P. B. 1574	41.7	47.5	—16.5	—13.3	—14.9
62–II–18–3 Sixty Day selection	54.2	47.7	— 4.0	—13.1	— 8.5
63–I–4 Burt (Extra Early) selection	50.2	52.4	— 8.1	— 8.4	— 8.2
Black Tartarian	52.0	55.9	— 6.5	— 5.0	— 5.7
120–9 Silvermine (Great Dakota) selection	67.3	69.5	+ 8.7	+ 8.9	+ 8.8
Early Champion P. B. 1572	39.7	42.5	—19.1	—17.7	—18.4
123–5 Welcome selection	69.8	68.9	+10.9	+ 9.0	+ 9.9
Swedish Select Regenerated P. B. 1747	58.5	57.8	— 0.6	— 1.7	— 1.1
125–20 Silvermine (Great American) selection	72.9	68.2	+13.7	+ 9.0	+11.3
Swedish Select P. B. 2036	55.9	58.2	— 3.5	— 0.7	— 2.1
5938–1 Sixty Day selection	55.2	55.7	— 4.9	— 2.8	— 3.8
American Banner P. B. 1737	66.2	68.0	+ 5.9	+ 9.8	+ 7.8

TABLE 8 — (*concluded*)

Variety	Yield in bushels		Gain or loss over check		Average
	1912	1913	1912	1913	
8a2–6–1 Clydesdale × Asia Minor Rustproof (3676)	48.0	56 9	—12.5	— 0.9	— 6.7
Morgan Feller P. B 1742	70.1	63 6	+ 9 4	+ 5 7	+ 7.5
Gold Mine P. B. 1739	63.1	61 4	+ 1 5	+ 3.0	+ 2.2
33a1–14 Burt selection	51.2	51 3	—10 8	— 7.5	— 9.1
White Plume P. B. 1743	51.7	57.8	—10.5	— 1.5	— 6 0
33a2–9–2 Burt (Early White) × Burt (Extra Early)	56 7	54.2	— 5 7	— 5 5	— 5.6
Black Anthony P. B. 1738	43.1	53 3	—19 5	— 6.9	—13 2
34a1–13–5 Burt (Early White) × Sixty Day	51 0	52 6	—11 8	— 8 0	— 9 9
Sensation P. B. 1744	50 2	56.1	—12.8	— 5 0	— 8 9
President P. B. 1748	73 9	67 3	+10 5	+ 5 8	+ 8 1
34a1–32 Burt (Early White) × Sixty Day	45 2	51 5	—18 4	—10 2	—14 3
Victory P. B. 1763	74.5	65 1	+10 9	+ 3 7	+ 7.3
49a1–25 Sixty Day × Clydesdale	57 1	46.3	— 6 2	—14 8	—10 5
White Bonanza P. B 1764	57 5	51.8	— 5.6	— 9 0	— 7 3
Fourth of July P. B. 1760	67 3	61.9	+ 4 7	+ 1.5	+ 3 1
Joanette P. B. 1762	57.0	60.4	— 5 1	+ 0.3	— 2.4
Seizure P. B. 1740	61 0	54 0	— 0 6	— 5 8	— 3 2
New White Cluster P. B. 636	61 7	55.3	— 5 5	— 4 2	— 4 8
49a2–27 Sixty Day × Clydesdale	58 4	57 5	— 3 7	— 1 7	— 2 7
Golden Fleece P. B. 1892	79 5	46.8	+10.9	—12 6*	— 0 8
Silver White Maine P. B. 639	59.5	58.7	—10.4	— 1.2	— 5.8
50a1–18–2 Sixty Day × Probsteier	59 5	51.9	— 3 7	— 8 6	— 6 1
Winter P. B. 641	31 5	20.8	—39 8	—40 2	—40 0
125–4 Silvermine (Great American) selection	64 8	66 1	+ 1 3	+ 4 6	+ 2.9
Garton 1174 P. B. 660	68 2	53 0	— 3 7	— 9.0	— 6 3
Garton 611 P. B. 661	70 2	56.8	— 1 6	— 5.7	— 3 6
Garton 855 P. B. 662	54 8	59.0	—16 8	— 4.1	—10.4
Avena Sativa Diffusa 16894	69 9	64 6	— 1 6	+ 1 0	— 0 3
Tartar King 21388	53 8	62 9	—17.5	— 0 8	— 9 1
Avena Sativa 21672	19 0	22 3	—52 0	—41 0	—46 5
Red Texas P. B. 1570	37 7	50.9	—33 2	—12 0	—22.6
131–19 Pringle's Progress selection	56 5	55.7	—14 2	— 6 8	—10.5
Alaska P. B. 1736	60 4	63 8	— 9 9	+ 1 7	— 4.1
Bland's White P. B. 1750	69 8	68.5	— 0 4	+ 6.8	+ 3.2
Early Mountain P. B. 1751	61.7	64 2	— 8.3	+ 2 9	— 2.7
Michigan Wonder P. B. 1752	80.6	66.8	+10 8	+ 5.9	+ 8 3
Progress P. B. 1753	74.5	60 9	+ 4 8	+ 0.4	+ 2.6
National P. B. 1754	84.8	68.1	+15 7	+ 8.3	+12.0
Scotch P. B. 1755	58 9	51.3	— 9 8	— 8 2	— 9.0
Sparrowbill P. B. 1756	62.9	57.3	— 5.5	— 1 9	— 3 7
New Danish White P. B. 1759	71.0	68.3	+ 3 0	+ 9.4	+ 6.2
Czar of Russia P. B. 1757	75.3	65.4	+ 7 7	+ 6.8	+ 7.2
Beardless Probsteier P. B. 1761	64.8	61.8	— 2.0	+ 3 5	+ 0.7
62–II–19–2 Sixty Day selection	55 3	56.4	—14.9	— 1.6	— 8.2
Siberian	55 2	66.9	— 0.1	+ 9 2	+ 4.5
S. P. I. 32280	.....	58.3	.....	+ 0.9	.....
Canada Cluster (check)	60.9	60.0	.....	.....	.....

*New seed was obtained for 1913, therefore the strain may be different.

From the table and the chart it is seen that there are a number of commercial varieties and strains that have given a better yield than the check; the average yield of all checks for the two years is 60.9 bushels and 60 bushels, respectively. A larger number fall below the check. The seven varieties that give the greatest average gain for the two years are: National, 12 bushels; Great Northern, 11.7 bushels; Silvermine selection 125–20, 11.3 bushels; Silvermine P B. 1571, 10.4 bushels; Welcome selection 123–5, 9.9 bushels; Lincoln, 9.9 bushels; and Silvermine selection 120–9, 8.8 bushels. Thus, out of these best seven there are three of the new selections that show up well. So far as value is concerned, all these may be classed together, since the experimental error will account for such a small difference as exists between the lowest and the highest gains. There is a difference of 3.2 bushels between the seven.

Among the varieties that fall below the yield of the check are some that have been used very extensively. Several lots of Swedish Select have fallen below the check. Other well-known varieties that failed to yield as well as the check for the past two years are Welcome, Big Four, White Tartar King, Clydesdale, Storm King, Ligowo, Abundance, White Russian, Early New Market, Kherson, Sixty Day, Golden Giant Side, Early Champion, and White Bonanza. These varieties, so far as the locality in which they were grown is concerned, have failed to produce as well as the ones mentioned in the preceding paragraph. To be sure, some of them have done well in other States, where growth conditions are different, but thus far they have failed to show worth in these tests.

Earlier in the bulletin the statement is made that variety tests should be continued for a series of years. This is true, and it is not the intention to draw definite conclusions from this table of the results for two years other than the fact that there is such a wide difference between some of the best-yielding strains and some of the poorer ones. It is not probable that two or three more years will change the results so that such types as Storm King, and the like, will outyield the Welcome and Silvermine selections or the Silvermine variety. Therefore some of these high-yielding strains may be recommended as good strains when they are to be grown under conditions similar to those at Ithaca.

The chart that illustrates these results graphically (Fig. 36) shows also the close agreement of most of the varieties and strains for the two years. The fact that there is such close agreement between these different sorts indicates that there is some justification in classing these into good and poor sorts.

The table and the chart show also that, so far as the series of hybrids and selections that have been tested are concerned, a very few are valuable

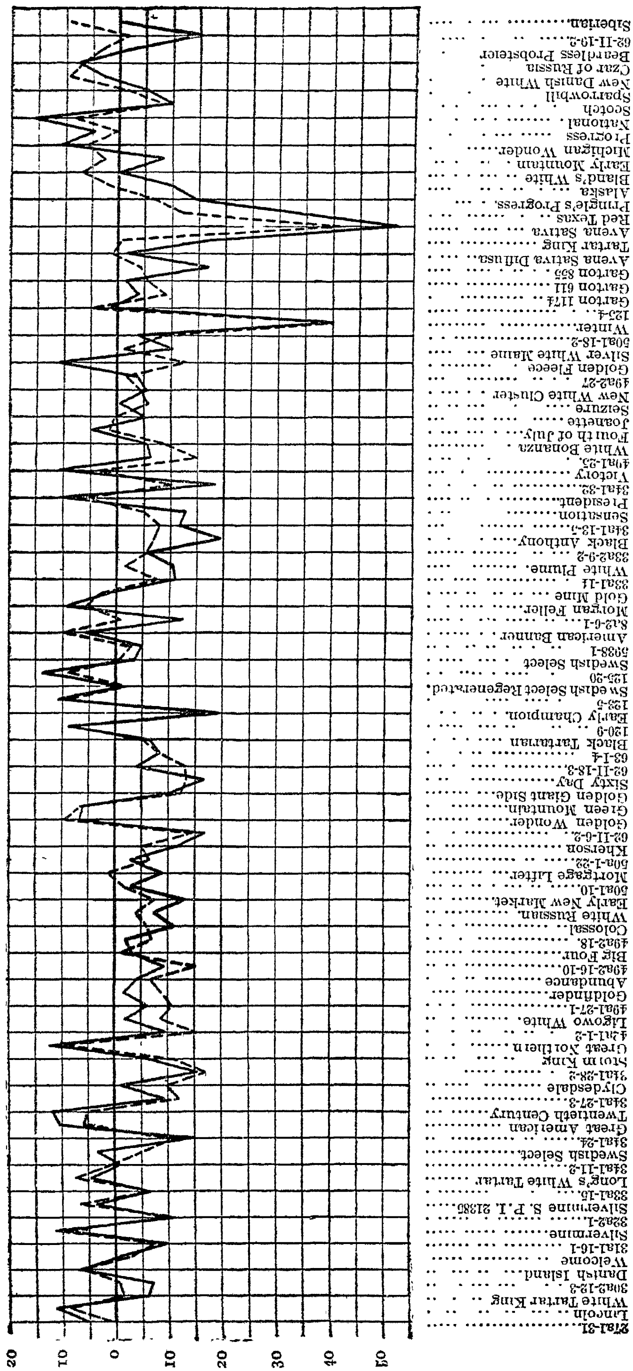

FIG. 36.—*Yields of all varieties and selections tested in both 1912 and 1913, in relation to their gain or loss over the check. Solid line 1912, broken line 1913*

and the remainder are practically worthless for New York conditions. The Silvermine and Welcome selections are valuable and the Garton's Tartar King × Clydesdale hybrid is still giving good results. The Burt × Sixty Day hybrid 34a1–11–2 has yielded for the last two years just the same on the average as the calculated check with which it was compared.

YIELD OF STRAW

The yield of straw is also a very important consideration in selecting an oat variety. This may be more important for the eastern States than for localities where more small grains are grown In connection with these experiments the yield of straw and chaff has been taken for the different varieties from 1911 to the present time This yield has been obtained by subtracting the weight of grain from the total weight before threshing; the difference is the weight of straw and chaff. These weights are then calculated to tons per acre and are thus expressed. The results are shown in Table 9:

TABLE 9. YIELD OF STRAW (EXPRESSED IN TONS PER ACRE) FOR THE VARIETIES GROWN IN 1911, 1912, AND 1913

Variety	1911	1912	1913	Average
Danish Island	1.29	1 44	1.56	1 43
27a1–31 Garton's Tartar King × Clydesdale	1 06	1.31	1 37	1 25
30a2–12–3 Burt (Early White) × Clydesdale	0 97	1.08	1.19	1.08
White Tartar King	1.13	1.21	1.34	1.23
31a1–16–1 Burt (Early White × Texas Red Rustproof)	0 94	1.08	1.16	1.06
Welcome	1 14	1.24	1.43	1.27
32a2–1 Burt (Early White) × Early Champion	1 07	1.10	1.07	1.08
33a1–15 Burt (Early White) × Burt (Extra Early)	1 15	1.00	1.04	1 06
Golden Giant Side	1.29	1.55	1.58	1.47
34a1–11–2 Burt (Early White) × Sixty Day	1 17	1.03	1.05	1 08
34a1–24 Burt (Early White) × Sixty Day	0.89	1.02	0.97	0 96
Black Tartarian	1 36	1.47	1 67	1.50
34a1–27–3 Burt (Early White) × Sixty Day	0 89	1.01	1.02	0.97
Swedish Select P.-B. 2036	1 37	1.16	1.36	1.30
34a1–28–2 Burt (Early White) × Sixty Day	0 82	0.83	0.93	0.86
Lincoln	1.26	1.47	1 60	1.44
42a1–1–2 Asia Minor Rustproof (3676) × Clydesdale	1.07	1.10	1.04	1.07
49a1–27–1 Sixty Day × Clydesdale	0.98	1.04	1.01	1.01
Long's White Tartar P. B. 1568	1.27	1.31	1.55	1 38
49a2–13 Sixty Day × Clydesdale	1.06	1.08	1.01	1.05
49a2–16–10 Sixty Day × Clydesdale	0.94	0 95	1.10	1.00
Early New Market P. B. 1569	1 27	1.05	1.23	1.18
49a2–18 Sixty Day × Clydesdale	1.00	1.12	1.07	1.06
Red Texas P. B. 1570	1.52	1.09	1.40	1.34
50a1–10 Sixty Day × Probsteier	1.07	1.06	1.00	1.04

TABLE 9 — (*continued*)

Variety	1911	1912	1913	Average
Silvermine P. B. 1571	1 43	1 29	1.44	1.39
50a1–22 Sixty Day × Probsteier	1 16	0 99	0 99	1.05
62–II–6–2 Sixty Day selection	0 99	0 91	0 87	0.92
Early Champion P. B. 1572	1 10	1.07	1.13	1.10
62–II–6–3 Sixty Day selection	0 91	0 90	1 42	1.08
Great American P. B. 1573	1 34	1 31	1 42	1.36
62–II–18–3 Sixty Day selection	0 99	1 01	0.99	1.00
Sixty Day P. B. 1574	0 93	0 98	0.87	0.93
63–I–4 Burt (Extra Early) selection	1 31	1 12	1.20	1.21
120–9 Silvermine (Great Dakota) selection	1 21	1 30	1 39	1.30
Swedish Select P. B. 1575	1 30	1.32	1.38	1.33
123–5 Welcome selection	1 27	1 26	1.36	1.30
Twentieth Century P. B. 1576	1 33	1 31	1.44	1.36
5938–1 Sixty Day selection	1 09	1 11	0.92	1.04
S. P. I. 21385 Silvermine	1 32	1 39	1.44	1.38
30a3–33 Burt (Early White) × Clydesdale	1.08	1 14	......	1.11
34a1–27–2 Burt (Early White) × Sixty Day	0 86	0 94	......	0.90
34a1–32–1 Burt (Early White) × Sixty Day	0 98	0.87	......	0.92
49a2–20 Sixty Day × Clydesdale	1 08	1 12	......	1.10
49a2–22 Sixty Day × Clydesdale	0 98	1 00	......	0.99
62–II–17–1 Sixty Day selection	0 92	0 95	......	0.93
62–II–18–1–1 Sixty Day selection	0.98	0.95	......	0 96
132–2 Sixty Day selection	0 89	0 91	......	0.90
142–1 Gold Mine selection	1 12	1 22	......	1.17
137–21 Early Champion selection	0 99	......	......	....
138–1 Early Champion (Prosperity) selection	1 02	......	......	....
138–5 Early Champion (Prosperity) selection	1.04	......	......	....
50a1–18–4	0 97	......	......	....
Clydesdale P. B. 640	...	1 34	1 28	1.31
Storm King S. P. I. 21387	.	1.28	1.23	1.25
Great Northern S. P. I 21389	....	1 34	1.50	1.42
Ligowo White S. P. I. 21390	.....	1 19	1.37	1.28
Goldfinder S. P. I 21391	..	1 52	1 64	1.58
Abundance S. P. I. 21392	......	1.24	1.31	1.27
Big Four S. P. I. 21386	...	1 30	1.42	1.36
Colossal S. P. I. 21393	....	1.15	1.34	1.24
White Russian	.....	1.14	1.27	1.20
Mortgage Lifter P. B. 638	....	1 17	1.31	1.24
Kherson P. B. 644	.....	0 92	1.00	0.96
Golden Wonder P. B. 647	.....	1 35	1.41	1.38
Green Mountain P. B. 658	......	1 38	1.55	1.46
Swedish Select Regenerated P. B. 1747	....	1.26	1.35	1.30
American Banner P. B. 1737	.....	1.41	1.61	1.51
8a2–6–1 Clydesdale × Asia Minor Rustproof (3676)	......	0.98	1.21	1.09
Morgan Feller P. B. 1742	......	1 40	1.51	1.45
Gold Mine P. B. 1739	......	1.40	1.30	1.35
33a1–14 Burt selection	......	1.04	1.11	1.07
White Plume P. B. 1743	......	1.26	1.32	1.29
33a2–9–2 Burt (Early White) × Burt (Extra Early)	......	1.10	1.07	1.08
Black Anthony P. B. 1738	......	1.48	1.70	1.59
34a1–13–5 Burt (Early White) × Sixty Day	......	0.97	1.02	0.99
Sensation P. B. 1744	......	1.28	1.34	1.31
President P. B. 1748	......	1.54	1.63	1.58
34a1–32 Burt (Early White) × Sixty Day	......	0.95	0.97	0.96

TABLE 9 — (*continued*)

Variety	1911	1912	1913	Average
Victory P. B. 1763	...	1 44	1 52	1 48
49a1–25 Sixty Day × Clydesdale	......	1 18	1 03	1 10
White Bonanza P. B. 1764	. . .	1 30	1.27	1.28
Fourth of July P. B. 1760	.	1 44	1 49	1.46
Joanette P. B. 1762	.	1 32	1 57	1.44
Seizure P. B. 1740	.	1 67	1.58	1.62
New White Cluster P. B. 636	...	1 34	1.11	1.22
49a2–27 Sixty Day × Clydesdale	.	1 17	1 05	1.11
Silver White Maine P. B. 639		1 42	1 27	1.34
50a1–18–2 Sixty Day × Probsteier	. . .	1.18	0.98	1.08
125–4 Silvermine (Great American) selection	. .	1 25	1.32	1.28
Garton 1174 P. B. 660	. ..	1 40	1.32	1.36
Garton 611 P. B. 661	. .	1.37	1.38	1.37
Garton 855 P. B. 662	.	1.31	1.29	1 30
Avena Sativa Diffusa 16894	. . .	1 50	1.49	1.49
Tartar King 21388	. . ..	1 24	1.32	1 28
Avena Sativa 21672		1 51	1.30	1 40
Alaska P. B. 1736	.	1.62	1 57	1 59
Bland's White P. B. 1750	. .	1 53	1.62	1 57
Early Mountain P. B. 1751	.	1 26	1.46	1.36
Michigan Wonder P. B. 1752	. .	1 51	1 44	1.47
Progress P. B. 1753	.....	1.41	1 38	1.39
National P. B. 1754	....	1 42	1.40	1.41
Scotch P. B. 1755	....	1 58	1 58	1.58
Sparrowbill P. B. 1756	.	1.73	1 63	1.68
New Danish White P. B. 1759	..	1.52	1 51	1.51
Czar of Russia P. B. 1757	. . .	1.61	1.53	1.57
Beardless Probsteier P. B. 1761	....	1 54	1.42	1 48
62–II–19–2 (White Strain) Sixty Day selection	.....	1 11	1.19	1.15
Siberian	.....	1.22	1.48	1.35
125–20 Silvermine (Great American) selection	.	1.34	1.33	1.33
131–19 Pringle's Progress selection	....	1.20	1.13	1.16
30a2–1 Burt (Early White) × Clydesdale	......	1 12	......	....
Kherson P. B. 1746	....	1.07	......	....
Swedish Select Albert P. B. 1745	. . ..	1.29	. ....	....
27a1–27 Garton's Tartar King × Clydesdale	.....	1.11	......	....
Swedish Select P. B. 1741	.....	1.22	......	. .....
31a1–16 Burt (Early White) × Texas Red Rust proof	. ....	1.00	......	....
34a1–28–1 Burt (Early White) × Sixty Day	. . . .	0.97	......	....
49a2–15 Sixty Day × Clydesdale	......	1.08	......	. .....
49a2–17 Sixty Day × Clydesdale	......	1 12	. ....	....
49a2–18–2 Sixty Day × Clydesdale	......	1 20	......	....
49a2–20–14 Sixty Day × Clydesdale	.....	1.07	. ....	... .
New Golden Fleece P. B. 637	. . . .	1.54	.... .	. . . . .
50a1–13 Sixty Day × Probsteier	...	1 23	......	.. ...
62–II–19–3 Sixty Day selection	... .	0 90	......	. . . .
Lincoln P. B. 642	. . ..	1.29	. ....	..... .
63–1–7 Burt (Extra Early) selection	.....	1.06	......	. .....
Silvermine P. B. 657	. . ..	1.36	......	....
Canada Cluster P. B. 1758	.....	0 71	......	.... .
62–II–19–1 Sixty Day selection	......	1.01	......	....
Golden Fleece P. B. 1892	......	......	1 28	....
S. P. I. 32280	......	......	1.33	....
118–7 Silvermine (Musselshell) selection	......	......	1.36	....
49a2–19–5 Sixty Day × Clydesdale	......	......	1.12	....

TABLE 9 — (*concluded*)

Variety	1911	1912	1913	Average
49a2–9 Sixty Day × Clydesdale			0.99	
38a1–9 Burt (Extra Early) × Clydesdale			1.25	
33a1–10–2 Burt selection			1.09	
33a1–7–6 Burt selection			1.09	
Avoine d'hiver P. B. 1878			1.70	
Black Mesdag P. B. 1913			1.39	
Avoine jaune hative d'yvois P. B. 1882			1.43	
Avoine noire hative d'Étampes P. B. 1883			1.55	
Avoine jaune de Flandre ou du Nord P. B. 1884			1.68	
Avoine de Pologne P. B. 1885			1.50	
Avoine hative de Siberie P. B. 1886			1.42	
Avoine noire de Hongrie P. B. 1887			1.52	
Avoine Joanette P. B. 1889			1.47	
Avoine blanche de Ligowo ameliorée P. B. 1890			1.32	
Avoine nue grosse P. B. 1891			1.50	
Improved American P. B. 1893			1.46	
Heavy Weight P. B. 1894			1.44	
Sagoyenathea P. B. 1895			1.42	
Sixty Day P. B. 1896			0.97	
New Johnson P. B. 1897			1.40	
English Wonder P. B. 1898			1.44	
Emperor William P. B. 1899			1.39	
Minnesota No. 6 P. B. 1900			1.32	
Black Egyptian P. B. 1901			1.56	
Minnesota No. 26 P. B. 1902			1.33	
Wisconsin Pedigree No. 1. P. B. 1903			1.54	
Wisconsin Pedigree No. 4 P. B. 1904			1.27	
Burt P. B. 1905			1.13	
White Spring Oats P. B. 1906			1.44	
Red Rustproof P. B. 1907			1.15	
White Sensation P. B. 1908			1.47	
Black Spring Oats P. B. 1909			1.02	
Excelsior P. B. 1910			1.41	
Daubeney P. B. 1911			1.03	
Bergs P. B. 1912			1.39	
Gold Rain P. B. 1914			1.67	
Wisconsin Pedigree No. 1 P. B. 1915			1.56	
Watson P. B. 1916			1.52	

From this table it is seen that there are certain varieties that give a high yield of straw each year, while others give a low yield. Swedish Select P. B. 2036 produces over a ton to the acre, while strain 34a1–28–2 produces less than a ton to the acre. Many other cases similar to this may be pointed out. It is apparent that most of the hybrids that have Burt or Sixty Day as one parent, and the selections from Burt or Sixty Day, are usually very low in yield of straw. The question naturally arises whether there is any relationship between yield of grain and yield of straw. Certain varieties may be selected that produce a large quantity of straw and a small quantity of grain, while on the other hand there

are those that produce a large quantity of grain with a relatively small quantity of straw. By selecting such isolated cases one might conclude that there is no relationship between the yield of grain and that of straw. This, however, is not the correct method of determining whether there is any relation between these two characters This is well illustrated by figures 37 and 38, which represent the yield of grain in bushels per acre and the yield of straw in tons for all varieties grown in 1911 and in 1912.

These charts are arranged as follows: The yield of grain in bushels is plotted in ascending order, and these points are connected by the solid

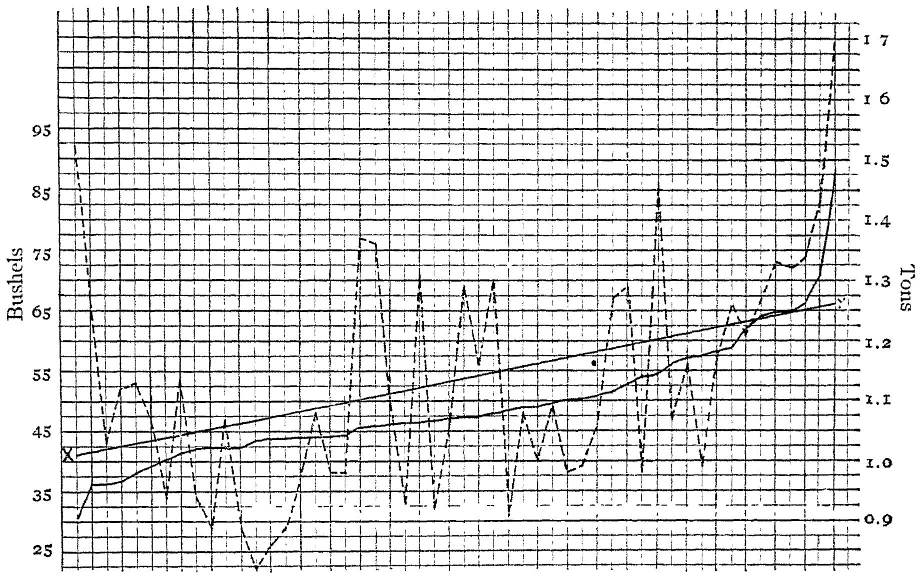

FIG. 37.— *Relation between yield of grain and yield of straw in oats for 1911. Solid line grain, broken line straw; xx, fitted straight line*

line, thus showing graphically the yield of grain in order from the lowest to the highest The yield of straw in tons per acre for each variety is plotted on the ordinate corresponding to its respective grain yield.

The relation is well illustrated by means of the straight line, which has been fitted by the method of least squares to the points representing the straw yields. The straight line has a decided tendency to slope upward in each case, thus showing that as the varieties tend to increase in yield of grain there is also an increase in yield of straw. The few cases that do not agree with this general conclusion are brought out very plainly in this graphic manner.

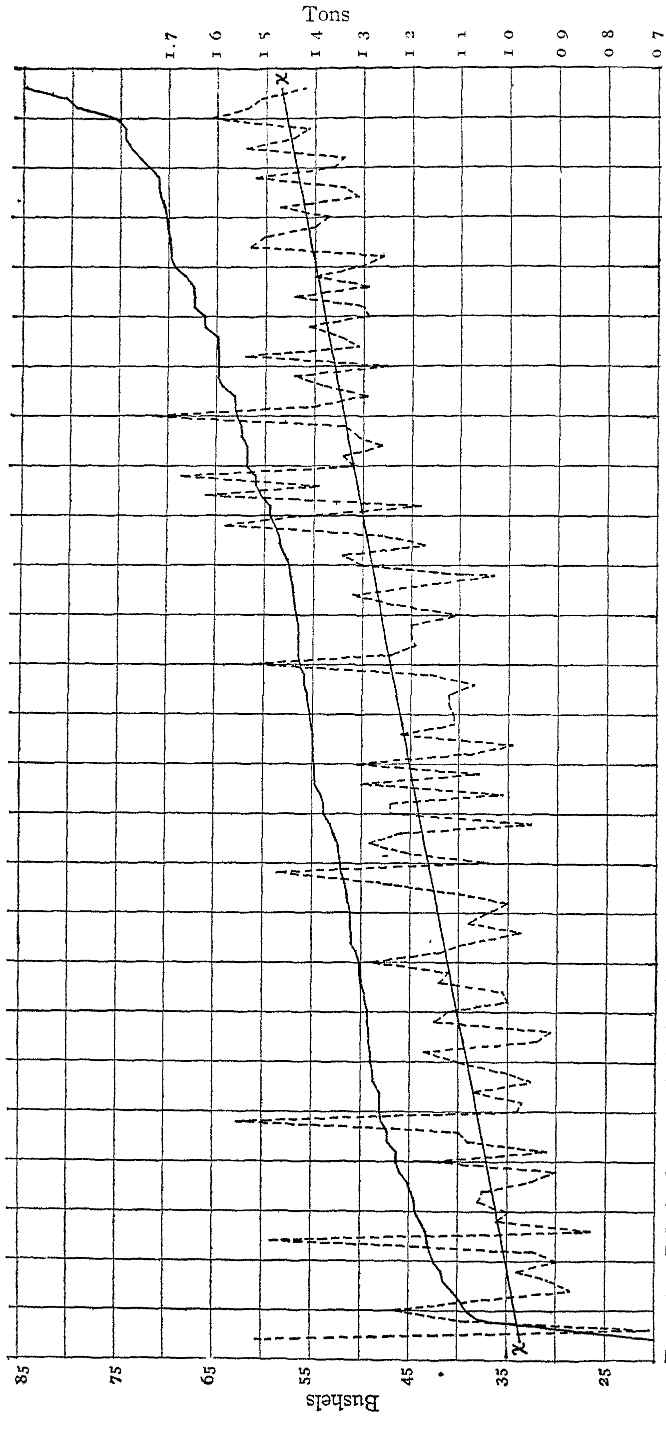

FIG. 38.—*Relation between yield of grain and yield of straw in oats for 1912. Solid line grain, broken line straw; xx, fitted straight line*

Another method of measuring this relationship between the yield of grain and the yield of straw is by means of correlation tables These tables have been made and the correlation has been calculated for the three years 1911, 1912, and 1913. The tables are illustrated in figures 39, 40, and 41.

Yield of straw in pounds

Yield of grain in bushels	800–900	900–1000	1000–1100	1100–1200	1200–1300	1300–1400	1400–1500	1500–1600	
30–34			1					1	2
34–38		1	1	1	1				4
38–42		2	1	1					4
42–46	5	3	3			2			13
46–50		5	4	1	2	1			13
50–54		2	1		2				5
54–58		1	1	2					4
58–62					2				2
62–66					1	2			3
66–70						1			1
70–74							1		1
	5	14	12	5	8	6	1	1	52

FIG. 39.—*Correlation between yield of straw and yield of grain for 1911*

r = .357 ± 082

Yield of straw in pounds

Yield of grain in bushels	800–900	900–1000	1000–1100	1100–1200	1200–1300	1300–1400	1400–1500	1500–1600	1600–1700	1700–1800	
34–38			1								1
38–42	1	2	1		1						5
42–46	3	3	3				1				10
46–50		6	6	6				1			19
50–54		3	4	3	6		1				17
54–58		1	5	10	2	5		1			24
58–62				2	2	3	1	1	2		11
62–66					1	4	2	1		1	9
66–70					4	1	4	1			10
70–74						5	2	2			9
74–78							2		1		3
78–82								1			1
82–86							1				1
	4	15	20	21	16	18	14	8	3	1	120

FIG. 40.—*Correlation between yield of straw and yield of grain for 1912*

r = .714 ± .030

Yield of straw in pounds

Yield of grain in bushels	800–900	900–1000	1000–1100	1100–1200	1200–1300	1300–1400	1400–1500	1500–1600	1600–1700	
38–42			1							1
42–46		2		1				2		5
46–50	2	1	4	2	1			1		11
50–54		3	5	3	6	3	2	3	2	27
54–58		4	4	3	3	8	1		2	25
58–62		1	2	1	3	5	8	1	1	22
62–66						5	5	5		15
66–70						7	8	6	3	24
70–74							2	2	1	5
74–78									1	1
	2	11	16	10	13	28	26	20	10	136

FIG 41.—*Correlation between yield of straw and yield of grain for 1913*

r = 500 ± 043

The correlation coefficients for the three years are .357 ± .082, .714 ± .030, and .500 ± .043, showing that there is a very good correlation between the two characters in question. It may be stated that one may expect the yield of grain to be proportional to the yield of straw, and that in general, for this locality, varieties that produce a good yield of straw will also produce a good quantity of grain.

Another important consideration in connection with the yield of straw is the ratio of straw to grain; or, in other words, how much straw is required in order to produce a pound of grain for the different varieties. This is important, for straw is not so valuable in some localities as in others, and also it may often be better to use those varieties requiring a relatively small quantity of straw in order to produce a pound of grain. The ratio of straw to grain has been calculated by dividing the number of pounds of straw by the number of pounds of grain. For example, the yield of Sixty Day for 1911 was 1478.4 pounds of grain and 1862 pounds of straw; the ratio of straw to grain was $\frac{1862.0}{1478.4}$, which is 1.26:1. This means that 1.26 pound of straw was required for each pound of grain produced. In the same manner the ratios for all the strains that were tested for the three years 1911, 1912, and 1913 have been calculated. These ratios are given in Table 10.

The question naturally arises whether this ratio varies greatly from year to year, or whether it is fairly constant for the same variety in the different years. If it is more or less constant it may be used as a factor in selecting varieties. With this in mind the data for the ratio are arranged in Table 10 so as to give some light on this question. In the table the yields of grain and of straw are given, as well as the ratios of straw to grain.

TABLE 10. WEIGHTS OF GRAIN AND OF STRAW IN POUNDS PER ACRE, AND RATIO OF STRAW TO GRAIN FOR 1911, 1912, AND 1913; ARRANGED IN ASCENDING ORDER OF THE RATIO FOR 1911

	1911			1912			1913		
	Weight of grain (pounds per acre)	Weight of straw (pounds per acre)	Ratio of straw to grain	Weight of grain (pounds per acre)	Weight of straw (pounds per acre)	Ratio of straw to grain	Weight of grain (pounds per acre)	Weight of straw (pounds per acre)	Ratio of straw to grain
62–II–18–3	1,836.8	1,984	1.08:1	1,734.4	2,028	1.17:1	1,526.4	1,976	1.29:1
62–II–18–1–1	1,724.7	1,954	1.13:1	1,702.4	1,908	1.12:1	...	...	...
34a1–28–2	1,385.6	1,636	1.18:1	1,385.6	1,652	1.19:1	1,472.0	1,856	1.26:1
62–II–6–3	1,545.5	1,816	1.18:1	1,360.0	1,798	1.32:1	...	...	...
50a1–10	1,795.2	2,146	1.20:1	1,753.6	2,112	1.20:1	1,900.8	1,994	1.05:1
125–20	2,828.8	3,416	1.21:1	2,332.8	2,676	1.15:1	2,182.4	2,666	1.22:1
49a2–22	1,600.0	1,954	1.22:1	1,587.2	2,010	1.27:1	...	...	...
120–9	1,983.9	2,424	1.22:1	2,153.6	2,598	1.21:1	2,224.0	2,790	1.25:1
34a1–27–2	1,395.2	1,722	1.23:1	1,571.2	1,876	1.19:1	...	...	...
62–II–6–2	1,606.4	1,978	1.23:1	1,328.0	1,818	1.37:1	1,481.6	1,746	1.18:1
62–II–17–1	1,491.2	1,838	1.23:1	1,372.8	1,908	1.39:1	...	...	...
123–5	2,048.0	2,546	1.24:1	2,233.6	2,528	1.13:1	2,204.8	2,730	1.24:1
34a1–11–2	1,859.2	2,338	1.26:1	1,833.6	2,054	1.12:1	1,977.6	2,108	1.07:1
Great American P. B. 1573	2,118.3	2,674	1.26:1	2,217.6	2,622	1.18:1	2,176.0	2,846	1.31:1
Sixty Day P. B. 1574	1,478.4	1,862	1.26:1	1,334.4	1,964	1.47:1	1,520.0	1,748	1.15:1
Silvermine P. B. 1571	2,262.4	2,866	1.27:1	2,121.6	2,580	1.22:1	2,281.6	2,890	1.27:1
50a1–22	1,827.2	2,314	1.27:1	1,760.0	1,972	1.12:1	1,734.4	1,982	1.14:1
132–2	1,395.2	1,774	1.27:1	1,571.2	1,830	1.16:1	...	...	...
49a2–18	1,561.5	2,006	1.28:1	1,779.2	2,234	1.26:1	1,750.4	2,140	1.22:1
S. P. I. 21385 (Silvermine)	2,073.6	2,644	1.28:1	1,948.8	2,790	1.43:1	2,128.0	2,884	1.35:1
Twentieth Century P. B. 1576	2,070.4	2,662	1.29:1	2,265.6	2,618	1.16:1	2,163.2	2,890	1.34:1
27a1–31	1,625.6	2,118	1.30:1	2,076.8	2,612	1.26:1	2,169.6	2,622	1.21:1
34a1–27–3	1,353.6	1,786	1.32:1	1,590.4	2,022	1.27:1	1,628.8	2,036	1.25:1
34a1–24	1,347.2	1,786	1.33:1	1,398.4	2,048	1.46:1	1,625.6	1,940	1.19:1
Lincoln	1,884.7	2,512	1.33:1	2,252.8	2,938	1.30:1	2,246.4	3,210	1.43:1
5938–1	1,584.0	2,186	1.38:1	1,766.4	2,220	1.26:1	1,782.4	1,848	1.04:1
30a2–12–3	1,401.6	1,948	1.39:1	1,638.4	2,170	1.32:1	1,932.8	2,378	1.23:1

TABLE 10—(*concluded*)

	1911			1912			1913		
	Weight of grain (pounds per acre)	Weight of straw (pounds per acre)	Ratio of straw to grain	Weight of grain (pounds per acre)	Weight of straw (pounds per acre)	Ratio of straw to grain	Weight of grain (pounds per acre)	Weight of straw (pounds per acre)	Ratio of straw to grain
34a1-32-1	1,404.8	1,954	1 39:1	1,296.0	1,740	1.34:1	....	.....	
49a1-27-1	1,414 4	1,960	1.39:1	1,670 4	2,080	1.25:1	1,654.4	2,030	1.23:1
49a2-20	1,555 1	2,158	1 39.1	1,577.6	2,246	1.42:1	....	.....	....
49a2-16-10	1,344.0	1,880	1.40:1	1,558 4	1,908	1.22:1	1,497.6	2,198	1.47:1
49a2-13	1,504.0	2,118	1.41:1	1,632 0	2,164	1 33:1	....	......	.....
31a1-16-1	1,286 4	1,890	1.47:1	1,510.4	2,164	1 43:1	1,702.4	2,328	1 37:1
Early Champion P. B. 1572	1,472.0	2,192	1.49:1	1,270 4	2,144	1 69:1	1,360 0	2,252	1 66:1
Danish Island	1,721 5	2,586	1.50:1	2,073 6	2,886	1 39:1	2,137.6	3,114	1 46:1
33a1-15	1,510 3	2,312	1.53:1	1,644 8	1,996	1.21:1	1,721.6	2,076	1.21:1
30a3-33	1,401 6	2,170	1 55:1	1,616 0	2,272	1.41:1	....	......	......
Long's White Tartar P. B. 1568	1,641 6	2,540	1.55:1	1,993 6	2,618	1.31:1	2,176.0	3,106	1 43:1
42a1-1-2	1,347.2	2,146	1.59:1	1,568 0	2,196	1.40:1	1,510.4	2,090	1 38:1
131-19	1,740.8	2,928	1 68:1	1,808 0	2,394	1.32:1	1,782 4	2,252	1 26:1
Swedish Select P. B. 1575	1,529.6	2,592	1.69:1	1,974.4	2,650	1.34:1	1,811.2	2,770	1.53:1
32a2-1	1,257.6	2,146	1.71:1	1,510 4	2,208	1.46:1	1,548 8	2,140	1 38.1
Golden Giant Side	1,507 2	2,576	1 71:1	1,529 6	3,098	2.03:1	1,545 6	3,164	2 05.1
Welcome	1,327 8	2,286	1.72:1	1,808.0	2,484	1 37:1	1,840 0	2,854	1 55:1
30a2-1	1,158.4	2,054	1.77:1	1,577.6	2,246	1.42:1	....	.....	......
63-1-4	1,478 4	2,628	1.78:1	1,606.4	2,240	1.39:1	1,676.8	2,402	1.43:1
White Tartar King	1,216 0	2,262	1 86:1	1,673.6	2,426	1 45:1	1,916.8	2,684	1.40:1
Black Tartarian	1,465 5	2,720	1.86:1	1,664.0	2,944	1.77:1	1,788 8	3,348	1 87:1
Swedish Select P. B. 2036	1,455.9	2,738	1.88:1	1,788 8	2,324	1.30:1	1,862 4	2,724	1 46:1
142-1	1,174.4	2,232	1.90:1	1,251 2	2,438	1.95:1	......	....	....
Early New Market P. B. 1569	1,155 2	2,546	2.20:1	1,433 6	2,092	1 46:1	1,718.4	2,462	1 43:1
Red Texas P. B. 1570	979 2	3,050	3.11:1	1,206 4	2,182	1 81:1	1,628 8	2,802	1.72:1

The table is arranged in the ascending order of the ratio of straw to grain for the 1911 results; that is, the strain having the lowest ratio in 1911 is placed first and the other strains are arranged in ascending order with respect to their ratios for that year. The yields and the ratios are also given for each of the strains tested in 1912 and 1913. It is obvious that the ratios for 1912 and 1913 do not follow the exact order that they do in 1911. It is apparent from this table, however, that in general those strains that gave the lowest ratios for 1911 also produced

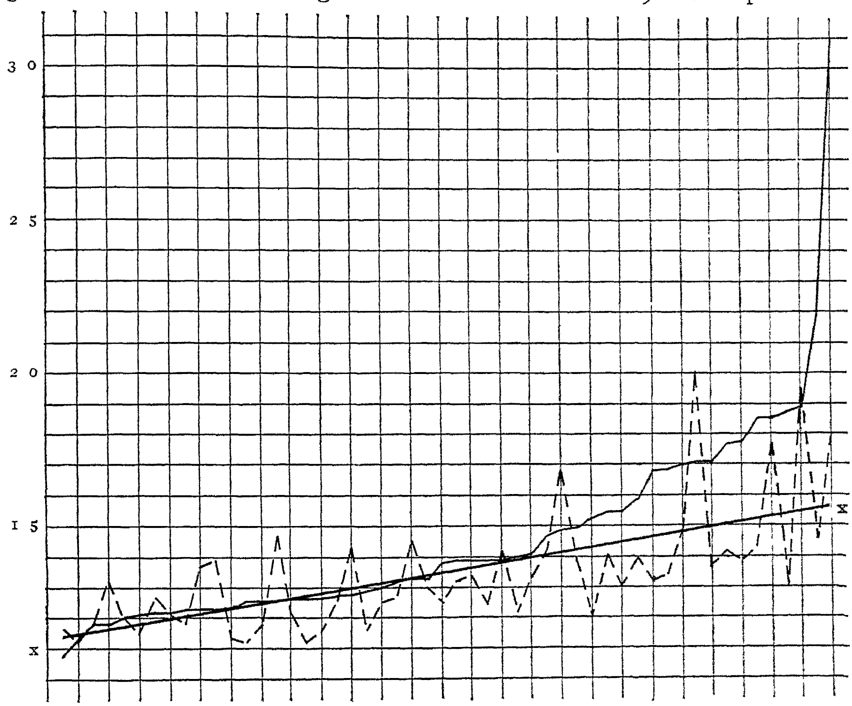

FIG. 42.— *Ratio of straw to grain for oats tested in 1911 and 1912. Solid line 1911, broken line 1912; xx, fitted straight line*

the lowest in 1912, and the highest ratios in 1912 came from the strains having a high ratio in 1911.

By dividing the different strains and varieties tested in 1911, 1912, and 1913 into two equal lots and obtaining the average ratios for the two years, the following results are obtained: The first 26 had an average ratio of 1.25 in 1911, and their average in 1912 was the same; the second 26 averaged 1.69 in 1911, and 1.45 in 1912; and the strains tested in 1913 from each lot gave an average of 1.22 and 1.48, respectively, showing a tendency to reproduce the ratio to some degree. In other words, the ratio of straw to grain seems fairly constant for the same strains in different years.

This is further illustrated by means of Fig. 42, which represents graphically the ratios obtained for the different strains for the two years 1911 and 1912. The solid line represents the ratios for the different strains for 1911, arranged in ascending order according to the ratio; the broken line represents the ratios for the same strains in 1912. The straight

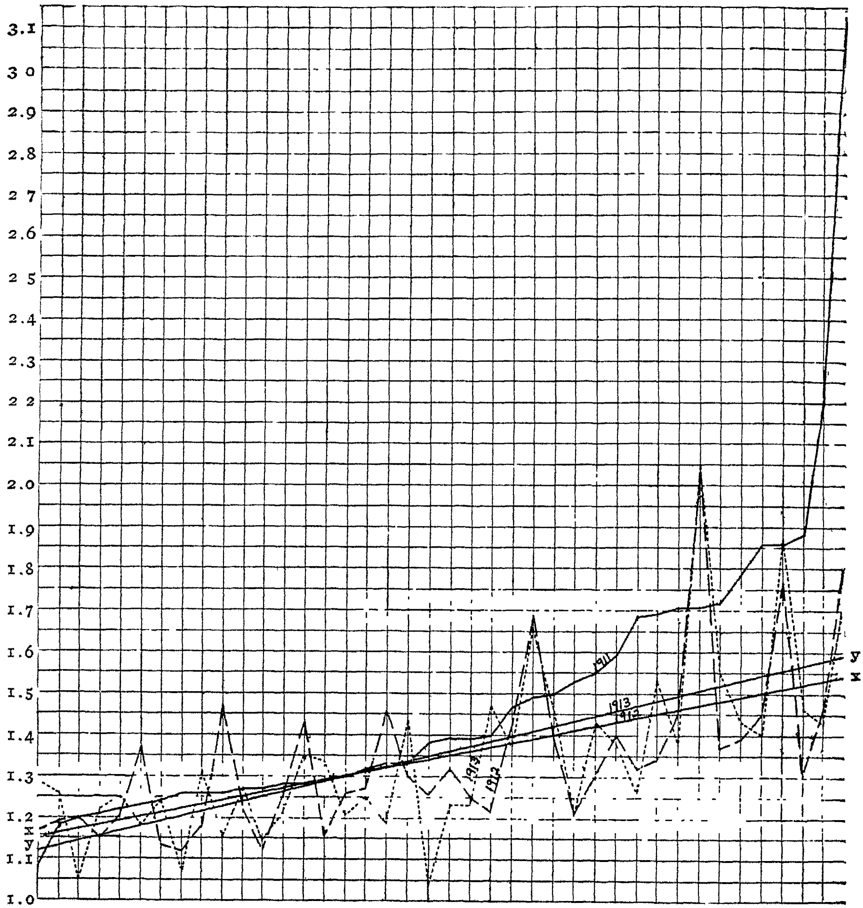

FIG. 43.—*Ratio of straw to grain for oats tested in 1911, 1912, and 1913. Solid line 1911, broken line 1912, dotted line 1913; xx, yy, fitted straight lines*

line xx, which has been fitted to the broken line by the method of least squares, shows a decided slope upward. The equation is y = 1.14 + .0083.

The data for the strains tested in 1911, 1912, and 1913 are shown graphically in Fig. 43. In this chart the ratios for 1911 are represented by the solid line and are plotted in ascending order; the ratios for the

same varieties for 1912 are illustrated by the broken line, and for 1913 by the dotted line. The straight lines xx and yy are fitted to the 1912 and the 1913 data by the method of least squares. The equations for the two years are $y = 1.15 + .01$ and $y = 1.12 + .012$, respectively, thus showing a decided upward slope. The fact that these straight lines from both figures show a decided upward slope indicates that there is a tendency for the ratio to be somewhat constant from year to year. This means that a certain amount of straw is required in order to produce a pound of grain each year, and may be considered a variety characteristic. There is a tendency for the ratio to be very low for certain varieties, while in others it is very high. For the three years, the average number of pounds of straw required in order to produce a pound of grain for the strains 50a1–10 and 34a1–11–2 is only 1.15, while, on the other hand, Golden Giant Side, Black Tartarian, and Red Texas require 1.93, 1.83, and 2.21, respectively.

It is interesting to compare the ratios of some of the commercial varieties and those of the selections obtained from these varieties. For example, the average ratio for the Welcome variety for the three years is 1.55, while that for 123–5, a selection from Welcome, is 1.20. This shows that a lower ratio has been obtained in the selection, or in other words, more grain for a given weight of straw. This is also brought out by the total weight of straw and of grain for these two lots. The total weight of straw for the Welcome variety was 7624 pounds, while the total weight for the selection was 7804 pounds, which is only slightly more. When it comes to the question of grain for the three years, however, the Welcome variety produced 4975.8 pounds, while the selection produced 6486.4 pounds — a gain of 47.2 bushels of grain, although the straw yield is nearly the same. Other cases might be pointed out, but the one mentioned is of the most importance and serves to illustrate the point.

From the table it is apparent that the early strains of the Sixty Day or Burt types, or hybrids of these with other varieties, are, in general, low in yield of straw, while some of the Silvermine and Welcome selections produce greater yields of straw. Some of the standard varieties yield more straw in comparison with the grain than do many of the new strains.

WEIGHT PER BUSHEL, WEIGHT PER ONE HUNDRED KERNELS, AND PERCENTAGE OF MEAT

The weights per bushel for the different varieties under test have been determined. The weights for 1912 are comparatively low, for the reason that the kind of thresher that was used then did not free all the awns from the kernels and therefore did not allow packing in the measure. More light seed was also retained than is the case when oats are threshed

in a large separator. The weight per bushel is obtained by the regular official grain-tester, which has been designed for the purpose. In order to be sure that all varieties were tested alike, an apparatus was designed so that all the oats dropped the same distance into the bucket and at the same rate. A large funnel, which held more than enough grain to fill the bucket, was suspended so that all grain dropped six inches. This could be changed so that those samples that had to be tested by means of a small tester were allowed to drop the same distance. The measures were then struck in the ordinary manner. Three to five tests were made from each variety and the average of these is here used.

These data, together with the weight of one hundred kernels and the percentage of meat, are given in Table 11. From this table it is seen that there is, as a rule, a tendency for the different varieties to give a high or a low weight per bushel for the different years. The White Tartar King variety gave an average of 34.33 pounds per bushel for the two years, which was the highest obtained; the lowest weight per bushel was obtained from the variety Winter.

TABLE 11. WEIGHT PER BUSHEL, PERCENTAGE OF MEAT, AND WEIGHT PER ONE HUNDRED KERNELS OF SOME OF THE VARIETIES GROWN IN 1912 AND 1913

Variety	Weight per bushel (in pounds)			Percentage of meat			Weight per hundred kernels (in grams)		
	1912	1913	Average	1912	1913	Average	1912	1913	Average
27a1-31 Garton's Tartar King × Clydesdale	33.00	34.81	33.90	68.6	68.8	68.7	2.337	2.492	2.414
Lincoln	32.00	31.50	31.75	71.1	67.0	69.0	2.578	2.584	2.581
White Tartar King	33.67	35.00	34.33	69.5	68.1	68.8	2.603	2.700	2.651
30a2-12-3 Burt (Early White) × Clydesdale	31.58	33.06	32.32	71.6	73.1	72.3	2.508	2.864	2.686
Danish Island	31.58	31.81	31.69	71.8	67.2	69.5	2.494	2.518	2.506
Welcome	32.00	34.00	33.00	69.3	68.5	68.9	2.573	2.604	2.588
31a1-16-1 Burt (Early White) × Texas Red Rustproof	30.08	34.50	32.29	68.4	70.9	69.6	2.422	2.720	2.571
Silvermine	30.83	34.00	32.41	67.8	67.0	67.4	2.278	2.584	2.431
32a2-1 Burt (Early White) × Early Champion	30.33	31.00	30.66	69.5	69.7	69.6	1.763	2.480	2.121
Silvermine S. P. I. 21385	31.67	31.81	31.74	69.6	67.9	68.7	2.409	2.490	2.449
33a1-15 Burt (Early White) × Burt (Extra Early)	29.17	30.12	29.64	70.3	70.1	70.2	2.356	2.538	2.447
Long's White Tartar	32.25	32.81	32.53	70.4	67.8	69.1	2.391	2.176	2.283
34a1-11-2 Burt (Early White) × Sixty Day	29.75	33.94	31.84	72.2	74.8	73.5	2.205	2.566	2.385
Swedish Select P. B. 1575	30.83	31.75	31.29	66.5	69.0	67.7	2.481	2.774	2.627
34a1-24 Burt (Early White) × Sixty Day	27.25	28.75	28.00	70.8	72.3	71.5	1.992	2.336	2.164
Great American	31.50	33.69	32.59	67.2	65.6	66.4	2.389	2.616	2.502
Twentieth Century	32.17	32.62	32.39	69.1	65.4	67.2	2.576	2.700	2.638
34a1-27-3 Burt (Early White) × Sixty Day	29.25	29.75	29.50	68.8	68.8	68.8	1.899	2.230	2.064
Clydesdale	32.67	31.25	31.96	68.9	67.6	68.2	2.644	2.746	2.695
34a1-28-2 Burt (Early White) × Sixty Day	30.08	30.56	30.32	70.6	70.2	70.4	1.791	2.056	1.923
Storm King	31.92	30.50	31.21	58.2	59.9	59.0	2.820	3.474	3.147
Great Northern	31.67	32.75	32.21	67.2	66.2	66.7	2.397	2.614	2.505
42a1-1-2 Asia Minor Rustproof (3676) × Clydesdale	30.33	31.44	30.88	66.9	70.4	68.6	2.293	2.850	2.571
Ligowo White	32.83	31.94	32.38	67.8	67.4	67.6	2.518	2.764	2.641
49a1-27-1 Sixty Day × Clydesdale	28.67	31.87	30.27	68.9	72.3	70.6	2.087	2.676	2.381
Goldfinder	31.83	27.75	29.79	69.1	65.8	67.4	2.379	2.430	2.404
49a2-16-10 Sixty Day × Clydesdale	30.42	31.87	31.14	68.3	70.8	69.5	2.281	2.896	2.588

TABLE II — (*concluded*)

Variety	Weight per bushel (in pounds)			Percentage of meat			Weight per hundred kernels (in grams)		
	1912	1913	Average	1912	1913	Average	1912	1913	Average
Big Four	32.33	32.75	32.54	66.0	69.0	67.5	2.451	2.760	2.605
49a2-18 Sixty Day × Clydesdale	31.75	33.56	32.65	70.2	74.2	72.2	2.123	3.024	2.573
Colossal	31.17	31.50	31.33	69.3	67.0	68.1	2.684	2.906	2.795
White Russian	33.42	33.50	33.46	66.2	63.8	65.0	2.357	2.980	2.668
Early New Market	31.83	33.00	32.41	61.5	60.9	61.2	2.737	3.584	3.160
50a1-10 Sixty Day × Probsteier	29.33	31.56	30.44	66.9	70.7	68.8	1.835	2.396	2.115
Mortgage Lifter	32.50	34.75	33.62	69.0	68.4	68.7	2.725	2.764	2.744
50a1-22 Sixty Day × Probsteier	30.50	33.37	31.93	70.1	72.6	71.3	1.800	2.336	2.068
Kherson P. B. 644	28.92	32.69	30.80	70.2	74.4	72.3	1.647	2.074	1.860
62-II-6-2 Sixty Day selection	26.25	30.37	28.31	68.6	70.2	69.4	1.555	2.066	1.810
Golden Wonder	32.50	34.69	33.59	66.9	70.2	68.5	2.384	2.830	2.607
Green Mountain	32.25	33.69	32.97	69.8	67.7	68.7	2.389	2.560	2.474
Golden Giant Side	30.67	30.06	30.36	70.1	66.8	68.4	2.031	2.166	2.098
Sixty Day	27.25	30.50	28.87	69.9	72.3	71.1	1.541	2.234	1.887
62-II-18-3 Sixty Day selection	30.67	31.25	30.96	71.7	72.5	72.1	1.861	2.534	2.197
63-I-4 Burt (Extra Early) selection	28.42	29.06	28.74	69.8	70.2	70.0	2.250	2.614	2.432
Black Tartarian	32.00	32.00	32.00	66.4	64.1	65.2	2.215	2.386	2.300
120-9 Silvermine (Great Dakota) selection	31.75	33.06	32.40	65.6	65.4	65.5	2.477	2.844	2.660
Early Champion	29.58	32.37	30.97	70.4	70.6	70.5	1.457	1.964	1.710
123-5 Welcome selection	31.50	33.12	32.31	65.9	68.0	66.9	2.470	2.824	2.647
Swedish Select Regenerated P. B. 1747	31.92	32.00	31.96	63.6	66.6	65.1	2.344	2.966	2.655
125-20 Silvermine (Great American) selection	31.92	33.00	32.46	66.8	62.2	64.5	2.328	2.760	2.544
Swedish Select P. B. 2036	31.92	34.25	33.08	69.2	68.0	68.6	2.430	2.780	2.605
5938-1 Sixty Day selection	27.42	32.00	29.71	68.1	71.1	69.6	1.566	2.260	1.913
American Banner	31.17	31.56	31.36	71.2	65.4	68.3	2.200	2.224	2.212
8a2-6-1 Clydesdale × Asia Minor Rustproof (3676)	26.92	29.69	28.30	66.4	66.4	66.4	2.695	3.064	2.879
Morgan Feller P. B. 1742	32.33	32.00	32.16	68.9	66.8	67.8	2.413	2.644	2.528
Gold Mine	33.42	34.50	33.96	70.5	69.5	70.0	2.616	2.770	2.693
33a1-14 Burt selection	26.92	31.06	28.99	71.0	70.6	70.8	2.271	2.726	2.498
White Plume	34.17	33.50	33.83	68.4	63.8	66.1	2.810	2.886	2.848
33a2-9-2 Burt (Early White) × Burt (Extra Early)	28.42	30.69	29.55	69.9	70.8	70.3	2.494	2.606	2.550
Black Anthony	31.75	30.50	31.12	70.4	61.5	65.9	2.357	2.316	2.336
34a1-13-5 Burt (Early White) × Sixty Day	31.50	32.44	31.97	69.0	71.9	70.4	2.304	2.406	2.355
Sensation	33.25	33.37	33.31	69.6	66.3	67.9	2.838	2.886	2.862
President	33.30	31.50	32.40	69.5	64.5	67.0	2.756	2.734	2.745
34a1-32 Burt (Early White) × Sixty Day	29.50	31.75	30.62	69.0	70.8	69.9	1.993	2.576	2.284
Victory	34.40	32.44	33.42	67.4	64.6	66.0	2.620	2.824	2.722
49a1-25 Sixty Day × Clydesdale	30.80	32.75	31.77	68.1	73.7	70.9	2.281	2.774	2.527
White Bonanza	32.30	31.50	31.90	68.1	67.4	67.7	2.667	2.834	2.750
Fourth of July	30.60	31.81	31.20	69.8	68.2	69.0	2.150	2.420	2.285
Joanette	30.75	31.62	31.18	74.0	73.8	73.9	2.047	2.250	2.148
Seizure	31.42	28.12	29.77	71.5	66.5	69.0	2.368	2.250	2.309
New White Cluster	31.67	33.19	32.43	69.0	70.1	69.5	2.201	2.716	2.458
49a2-27 Sixty Day × Clydesdale	28.75	32.37	30.56	69.1	70.4	69.7	1.844	2.320	2.082
Silver White Maine	31.75	34.69	33.22	69.0	67.7	68.3	2.528	2.954	2.741
50a1-18-2 Sixty Day × Probsteier	29.50	33.25	31.37	66.8	68.7	67.7	2.063	2.656	2.359
Winter	28.50	24.50	26.50	68.2	62.5	65.3	1.940	1.894	1.917
125-4 Silvermine (Great American) selection	31.67	33.00	32.33	67.0	64.2	65.6	2.380	2.844	2.612
Garton 1174	31.67	31.62	31.64	69.6	66.2	67.9	2.714	2.940	2.827
Garton 611	31.17	32.50	31.83	70.2	64.0	67.1	2.771	3.000	2.885
Garton 855	32.08	31.94	32.01	67.8	60.9	64.3	2.841	3.196	3.018
Avena Sativa Diffusa	28.67	32.00	30.33	70.6	68.8	69.7	1.772	2.306	2.039
Tartar King	......	33.81	.....	67.6	63.4	65.5	2.719	3.184	2.951
Red Texas	29.08	31.50	30.29	67.1	66.3	66.7	2.640	2.534	2.587
Pringle's Progress	26.92	31.19	29.05	66.1	66.0	66.0	1.980	2.644	2.312
Alaska	29.00	32.00	30.50	71.5	69.1	70.3	1.682	2.180	1.931
Bland's White	32.17	32.62	32.39	71.1	68.3	69.7	2.414	2.554	2.484
Early Mountain	32.17	34.62	33.39	65.7	62.0	63.8	2.278	2.580	2.429
Michigan Wonder	30.67	32.50	31.58	67.7	65.8	66.7	2.482	2.850	2.666
Progress	31.25	31.56	31.40	69.0	67.6	68.3	2.395	2.664	2.529
National	30.67	31.94	31.30	66.3	63.8	65.0	2.438	2.710	2.574
Scotch	31.50	30.87	31.18	66.7	61.4	64.0	3.322	3.364	3.343
Sparrowbill	34.25	31.50	32.87	70.8	62.6	66.7	2.177	2.290	2.233
New Danish White	31.25	32.94	32.09	70.3	68.2	69.2	2.084	2.224	2.154
Czar of Russia	30.00	31.56	30.78	70.5	67.5	69.0	1.936	2.274	2.105
Beardless Probsteier	30.83	28.81	29.82	69.5	67.5	68.5	2.258	2.524	2.391

Weight per bushel is important, since it is one of the points taken into consideration when grading oats. From the data at hand, however, it does not follow that because an oat gives a heavy weight per bushel it will yield well. The highest weight per bushel was obtained from a variety that did not yield so well as the check. When oats are offered for seed merely because they give a heavy weight per bushel, it does not necessarily follow that they will yield well Such varieties as Swedish Select, and the like, for which the claim is made that they have a heavy weight per bushel, do not hold up to this weight per bushel when grown in this locality, neither do they yield well in many cases.

It is therefore not good practice to select a variety merely because it gives a heavy weight per bushel unless this is accompanied with a heavy yield per acre. When all the varieties that have been grown in 1912 and 1913 are considered, it is found that weight per bushel is correlated with yield per acre. The coefficients for the two years are .442 ± .050 and .533 ± 041. The relation between the weight per bushel for the different strains for 1912 and 1913 is shown graphically by means of Fig. 44. The solid line represents the weights for 1912 and the broken line the corresponding weights for 1913. It is seen that in general there is very good agreement for the two years. Certain exceptions are apparent, when the weights for the two years do not closely agree.

Certain studies were made on the kernels of the different varieties in order to learn whether there were any particular shapes that tended to make for high weight per bushel. The length and breadth of a number of kernels from each variety were determined, and these characters were compared with weight per bushel.

The length of kernel was correlated with weight per bushel for the two years 1912 and 1913, and the correlation coefficients were found to be —.221 ± .059 and — .500 ± .043, respectively. In other words, as the kernels became longer the weight per bushel became less. The varieties having a long kernel, in general, have a smaller weight per bushel than those having a shorter kernel.

The breadth of kernel was divided by the length in order to find the ratio between the two characters. The kernels that were broader in comparison to their length would have a higher ratio. This ratio was then correlated with weight per bushel for the two years, and the correlation coefficients were found to be .751 ± .027 and .626 ± .035, respectively, thus indicating that those varieties possessing kernels with greater breadth in comparison to their length gave a higher weight per bushel.

One can readily understand why the long kernels would not give a high weight per bushel when the method of taking the weights is considered. The long seed would tend to pile up and not pack together well, thus

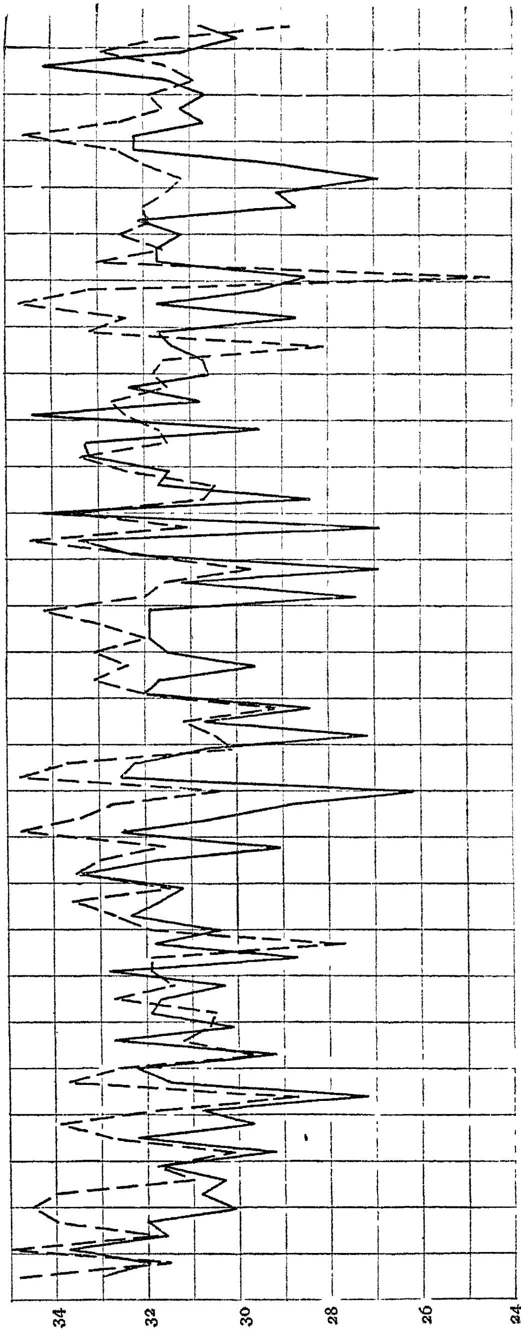

FIG. 44.— *Relation of weight per bushel (in pounds) for the same varieties for 1912 and 1913. Solid line 1912, broken line 1913*

leaving more unfilled space in the measure, which would naturally mean lighter weight. The kernels having greater breadth in comparison with their length would tend to pack down better in the measure, leaving little unfilled space, thereby giving a higher weight per bushel. This fact should be kept in mind when selecting an oat variety for seed. If two varieties are equally good otherwise, it would be well to select the one having the better-shaped kernel, which would usually be the shorter, plumper one, provided it is well filled. The two types of kernels are illustrated in Fig. 45.

Another very important consideration in oats is the amount of meat. There is a common belief that a large seed is all that is necessary to mark a good oat. As a rule, the large-seeded sorts sell better for seed

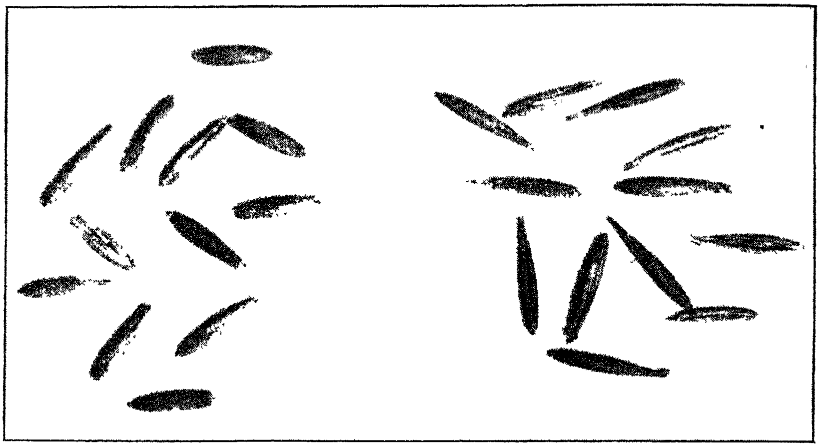

FIG. 45.— *Two types of kernel shapes; type of kernel on left gives high weight per bushel, that on right gives low weight*

when offered in competition with the smaller-seeded ones. During the tests of the different varieties, data have been taken on the size of seed or the average weight and the percentage of meat, together with some other kernel measurements. The relation of percentage of meat for the two years is shown graphically by Fig. 46. There are some exceptions, but in general there is a relation, the strains being high or low each year.

The average weight of seed was obtained by weighing a composite lot of fifty or one hundred seeds. Several samples were taken from each variety and the average was used to express the average weight. The same seeds were then hulled by hand and the weights of the meats were obtained after hulling. Since there were several composite lots taken from each variety, the average is given in the table. From these data

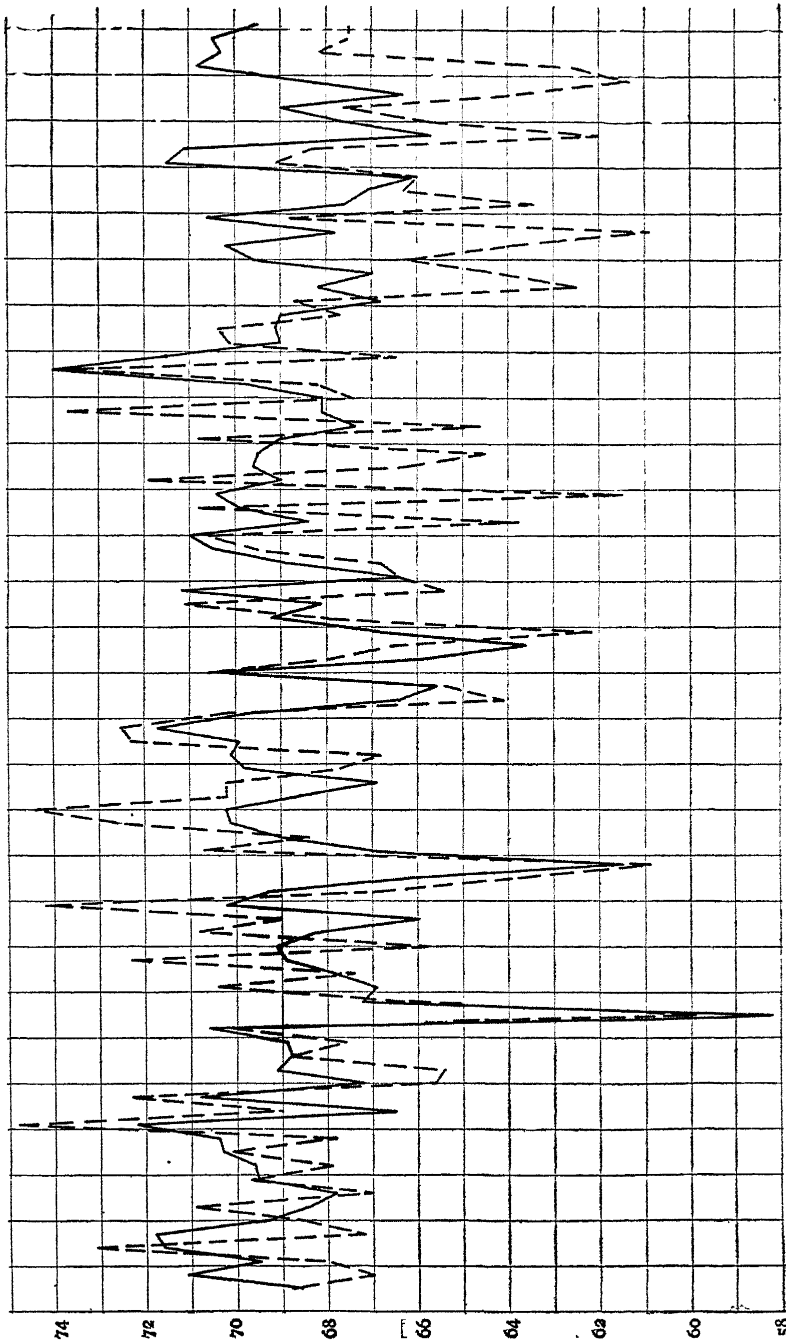

FIG. 46.— *Relation of percentage of meat for the same varieties for 1912 and 1913. Solid line 1912, broken line 1913*

there is seen a great variation in weight per hundred seeds and in percentage of meat. For example, the average weight per hundred seeds from the Early Champion variety is 1.710 gram, while the weight per hundred seeds from Scotch is 3.343 grams — almost twice as much.

When one examines the weight per hundred seeds and the percentage of meat, it is apparent that the large seeds do not always produce the largest percentage of meat. The fact is that the highest percentages of meat are obtained from those varieties having a comparatively small kernel. Of nineteen varieties having a percentage of meat of more than 70, all but four have a kernel weight of less than 2.5 grams per hundred; while of the seven varieties whose percentage of meat is 65 or less, four have a kernel weight of over 3 grams. This indicates that there is no relation between large kernels and high percentage of meat in the sense that the two are found together.

All the varieties studied for 1912 and 1913 were arranged in correlation tables with respect to the two characters, weight per hundred kernels and percentage of meat, and there was found a negative correlation of $-.237 \pm .058$ and $-.188 \pm .055$. These coefficients are not large, and when one considers their probable errors they are not conclusive other than for the fact that they are negative both years. This indicates that if any relation exists between these characters it is in the direction that large seeds would tend to have a thick hull and therefore a low percentage of meat. For the conditions under which these oats were grown the small- or medium-seeded strains are the more desirable.

These studies indicate further that the varieties tending to produce large quantities of straw give, on the other hand, a large quantity of hull and a comparatively small quantity of meat. The correlation between percentage of meat and yield of straw for the varieties grown in 1913 gave a correlation coefficient of $-.621 \pm .035$, showing that as the yield of straw increased there was a decrease in percentage of meat.

The correlation between length of kernel and percentage of meat was also determined, in order to see whether long kernels gave more meat than short ones. The correlation coefficients were found to be $-.108 \pm .061$ and $.040 \pm .057$ for the two years, thus showing that there was no relation between length of seed and amount of meat.

Correlation tables were made on the percentage of meat and weight per bushel, but no correlation was found. These results may not be conclusive, since they are for only two years and all the varieties of oats now on the market were not included; yet one will notice that a large number of the more common varieties were used. The fact that there is no correlation between weight per bushel and percentage of meat would

indicate that there is enough balance between the hull and the meat so that the correlation between these characters remains near zero.

So far as the weight of seed itself is concerned, it was found that as a rule large-seeded strains tended to give a slightly larger yield. The weight per hundred seeds was correlated with the yield for each of the years 1912 and 1913, and the correlation coefficients for the two years are $.347 \pm .054$ and $.230 \pm .054$. So far as these coefficients are concerned, while they are not conclusive there is a tendency for the large seed to be associated with large yield. However, when one considers the fact that there is a negative correlation between weight per hundred seeds and percentage of meat, care should be exercised against selecting a strain for seed merely because it has large seed. The seeds should be thin-hulled and well filled with meat. A medium-sized seed would be better for this locality for both yield and percentage of meat.

The foregoing data present some important facts regarding the value of certain varieties for New York State. This crop is of enough importance in the State so that great care should be taken in selecting a variety for commercial use. While the variety tests in which the varieties have been tested for only two years are not conclusive, yet they are suggestive, so that one gains some information regarding the value of the different sorts.

SUMMARY

The results may be summed up in the following paragraphs:

Data have been presented showing the results of the hybrids and the selections obtained from the Office of Cereal Investigations of the United States Department of Agriculture. Some of these, such as Silvermine selections 120–9 and 125–20, Welcome selection 123–5, and the Garton's Tartar King × Clydesdale hybrid 27a1–31, have proved to be of value for New York State.

Place variation tends to operate to such an extent that variety tests should be continued over several years before definite conclusions may be drawn.

The later oats, such as the Lincoln or the Silvermine type, have given better results for this locality than have the early oats, such as Sixty Day.

The results show that the yield of straw tends to follow closely the yield of grain, and that varieties producing heavy yields of straw usually produce low quantities of meat.

The ratio of grain to straw seems to be rather constant from year to year.

The weights per bushel for the different years for the same varieties are comparatively high or low as the case may be.

Weight per bushel depends considerably on the shape of the kernels. A high weight per bushel does not necessarily mean a high-yielding variety.

The weight per hundred kernels was found to vary greatly for the different varieties. There is a slight tendency for heavy-yielding varieties to have larger seed.

The percentage of meat differed greatly for the different varieties. Certain varieties give such a low amount of meat that they should not be grown at all commercially.

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THE COLLEGE OF AGRICULTURE

Department of Farm Management

AGRICULTURAL SURVEYS

By G. F. WARREN

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AGRICULTURAL SURVEYS

G. F. Warren

The object of this circular is to assist in answering the large number of requests from various institutions concerning the methods of doing agricultural survey work. The writer's experience has been limited to orchard and farm-management surveys, but the discussions apply equally well to nearly any kind of surveys. Most of the principles were given at the Graduate School of Agriculture in 1908 and again in 1912.

During the last few years there has been a great development of the survey idea. This is in line with other scientific advancement. It indicates a desire first to find out the facts. The word " survey " is sometimes used to include many kinds of desultory work, just as much desultory work is sheltered under the name of laboratory research. Unless the work results in information of scientific value, it should not be called a survey. Or, if this word is to be used for all kinds of observational generalities, a new word must be found for describing scientific work, the data for which are gathered by the survey method.

OBJECTS OF AGRICULTURAL SURVEYS

First find out the facts.— Much discussion is heard as to why boys leave the farm, the marketing of farm products, agricultural credit, fertilizers, farm barns, farm homes, how to feed cows, how to raise corn, and an nfinite number of other rural questions. In the vast majority of cases too little is known about the facts of farm conditions and farm practice. Before spending too much time in talking about boys' leaving the farm, it is well to do some statistical work in order to learn how many boys are leaving the farm, whether they are leaving as much as formerly, what kinds of farms they are leaving, and whether those who go to cities are worse off or better off than their brothers who stayed at home. A few instances mean nothing. Results from many must be considered before correct conclusions can be drawn.

In one county in New York it was found that the boys were leaving the small farms and were staying on the 200-acre farms. They appear to be leaving the small farms because there is not enough profitable work to keep them busy.

The first step in studying the marketing of farm products is to follow the products to the consumer and study the handling and the price increases at each step. This must be done for enough shipments to determine the normal conditions.

The best way to begin the study of agricultural credit is to study conditions in America. We shall also want to know what Europe is doing, but first we should have a clear knowledge of facts here. What proportion of our farmers have bank accounts? What proportion of them pay cash for feed, machinery, fertilizers, and groceries? Who furnishes the vast credit facilities that are necessary for handling the credit on machinery? What rate of interest does the farmer really pay when increased price is included, as it must be? Are the agencies that furnish this credit the best ones? Are we imposing on our machinery manufacturers and our fertilizer dealers a banking business, as well as manufacturing? Who can answer these questions? A slight study of conditions in New York State indicates that farmers pay about 15 per cent interest on machinery. The legal rate of interest is 6 per cent. Therefore the farmer pays 6 per cent as interest and the balance in increased price when he buys on time.

Farmers have been using fertilizers for years. They have conducted hundreds of experiments. The first step in studying fertilizer problems in an eastern State should be to determine the present farm practice. This cannot be done by merely being familiar with farming, or speaking at farmers' meetings. Ideas gained in this way are often shown to be misleading when compared with a statistical study in which the practice of every farmer in a region is recorded.

Recently the writer heard a lecture on farm buildings, in which all the lantern slides that were commended were of suburban homes and barns on rich men's "folly farms." The only farm buildings shown were used as horrible examples. The writer asked whether the years of study had not resulted in finding any satisfactory buildings on real farms. The answer was no. But there are hundreds of examples of farm buildings excellently adapted to their conditions. One of the first of these conditions is that the buildings shall not represent an undue proportion of the farmer's capital. The place to begin the study of farm buildings is on farms, not on a college campus nor on a rich man's country place.

What is the usual farm practice in feeding cows in a dairy section? Not the practice of some few farmers that the college person happens to know, but the practice of the majority and the variations from this practice by individuals.

In nearly all cases public workers see much more of the farmers who are following methods recommended than of the normal farmer. The resulting idea of farm conditions is far from correct.

Importance of knowing the normal. Perhaps the first object of a survey is to find out the normal conditions. After this information is obtained it is possible to study the more successful and the less successful with

intelligence. The strikingly unusual has too often been accepted as a model. Bulletins have been written describing in detail the methods used on some peculiar farm, under the impression that it was doing much better than the normal, less spectacular enterprise. Survey methods often show that such farms or practices are really not successful.

One of the most firmly established traits of human nature is to notice striking exceptions and make rules from them. The normal, or usual thing, is too common to be noticed It is said that unlike persons attract each other. Statistical measurements of husbands and wives indicate that the opposite is the rule. The normal condition is so common as to attract little attention. The exceptions are conspicuous, attract attention, and result in exactly the wrong conclusion.

Nearly every one believes that if there is a warm fall, we shall have to " pay for it " by having bad weather in winter. Statistical records indicate that there is no such relationship. Whatever the fall, we should expect the normal winter and be prepared for the variations from that normal that the records indicate may occur.

When a noted veterinarian was called across a continent to see whether the fumes from a smelter were hurting range horses, he did not spend much time on the sick horses. He first went to a similar valley sixty miles away and killed a number of horses in order to study the normal. He found the same condition that was attributed to injury from fumes. He first determined the normal. Needless to say, his testimony won the case.

If one does not know the normal, and the usual variations from that normal, he is more likely to attribute the success or the failure of a farm to the wrong than to the right cause. Not infrequently the very worst point in the system is picked out as the cause of success, just because that point is striking.

Mere travel through a country, visiting on farms, or speaking to farmers in a region is likely to result in memory of the striking or the unusual. It in no way takes the place of statistical study. The very assurance that comes from observation sometimes makes persons with such experience the last to believe the truth of statistical studies, just as the practical breeder who sees " instances " is sometimes the last to believe the results of statistical studies of inheritance. Survey methods disprove many popular notions about farming, just as biometrical methods disprove old superstitions about heredity.

Some facts can be determined only by studying farms. There are many kinds of agricultural information that can be determined only by survey methods, because the facts exist on the farms and nowhere else. The cost of producing a crop may be determined for a college farm, but this tells very little about the cost on regular farms.

The relative amount of food fed to a cow and a sheep by farmers can be determined only by studies on farms. One scientist stated that the results given for Tompkins county, New York, were wrong because they did not agree with some results from a German experiment station. Investigations at experiment stations cannot determine what the farmers feed. The only possible place to study this problem is on the farms.

Survey methods often the cheapest. Before any experiment station knew of the existence of leaf-blister mite on apples, one farmer in Orleans county, New York, was controlling the mite by spraying.[1] The oldest experiment on sod versus tillage for apple trees was conducted by a farmer. The results of five or more years of sod treatment of 88 orchards in Wayne and Orleans counties, New York — reported in bulletins 226 and 229 of this station — were obtained at less cost than would have been necessary in conducting a single experiment.

Experiments on a single orchard are not conclusive because conditions are so variable. The error in a single experiment due to not having selected a typical orchard is usually greater than the error from less accurate records when many orchards are included. Both the careful experiment-station test and the results of surveys are needed in order to fully answer most problems. Survey work should ordinarily precede the starting of tests because the results are often of great value in planning experiments.

Practice usually outruns science. The value of generations of experience is not always appreciated. Doctor Hall, formerly Director of the Rothamsted Experiment Station, shows his keen understanding of this in his statement on page vi of "The Soil": ". . . agriculture is the oldest and most widespread art the world has known, the application of scientific method to it is very much an affair of the day before yesterday. Nor can we see our way to any radical acceleration of the turnover of agricultural operations that shall be economical; the seasons and the vital processes of the living organism are stubborn facts, unshapable as yet by man with all his novel powers. But even if the best farming practice is still a step beyond its complete explanation by science, yet the most practical man will find his perception stimulated and his power of dealing with an emergency quickened by an appreciation of the reasons underlying the tradition in which he has been trained. . . ."

Limitations of survey work. It is of course useless to do survey work on methods of growing alfalfa if no alfalfa is grown in the region. There should be some years of experience with a problem before the data for surveys exist.

There are cases in which the opinions of farmers should be gathered. In order to make these opinions of any value it is necessary that farmers

[1] Cornell University Agricultural Experiment Station. Bulletin 226, pages 267, 340.

should have had experience with the problem. Usually results are not based on opinions, but on figures. We do not ask farmers what they think about tilling orchards. We learn the tillage practice and the yields, and find the results. Farmers are likely to draw conclusions from exceptional cases, just as are all other persons. Statistics are very much better than opinions.

Order for making surveys. When survey work can be done in a logical order it would appear that the topographic map prepared by the United States Geological Survey should come first. This locates roads and houses, as well as gives the contour lines. A soil survey is the logical next step. Following this should come a farm-management survey. This gives a great variety of information, as is indicated by the blank in the back part of Bulletin 295 of this station. Following the farm-management survey should come special studies of particular crops or animals, and social and historical studies.

It is not likely that this exact order can often be followed, yet there are advantages in it Soil changes are likely to follow contour lines fairly closely. The topographic map is almost a necessity in soil-survey work. The primary basis of prosperity and community conditions is the soil. Any study of crops, animals, or people that does not give consideration to the soil is likely to be confusing. The farm-management survey determines the labor income. It also finds the crops and the yields, the animals and their production, as well as a large amount of other information. It discovers the more important problems. It shows the relation of each of the crops and the kinds of animals to the farming as a whole. It is often helpful in finding the more important producers of any article. It is logically followed by studies of the more important crops and animals. The most important interests should have first attention.

DEVELOPMENT OF STATISTICAL AGRICULTURAL SURVEYS

The first start in agricultural surveys at Cornell was the work of L. H. Bailey, who made a number of field studies of horticultural conditions in New York. In 1903 Professor John Craig thought it desirable to start an orchard survey, and the work was assigned to the writer, because he had been studying the then new subject of soil-mapping. The intention was to map the soil and study its relationship to apple-growing. It soon became evident that, in the region studied, other factors were more important than the soil. The writer therefore changed from a soil survey to a statistical survey.

The results of this work were published in bulletins 226 and 229 of this station. This type of work has been continued to cover five counties. Some of the results are published in bulletins 262 and 307. So far as the

writer knows, these bulletins were the first farm-statistical studies made by this method.

In teaching classes in farm management Professor Hunt required each student to get a financial record of his home farm and calculate the labor income. The writer believed that this method could be extended so as to include all the farms in a region. In 1907 such records were obtained from all the farms in two townships. At this time the work of organizing the department was so heavy that there was not time to work with the students in the field, and as a result the records were inaccurate. For this reason they were never published. However, the conclusions were in accord with our later work. The next year the work was checked more carefully and resulted in Bulletin 295, "An Agricultural Survey of Tompkins County." Since that time surveys have been made in two other counties, the results of which will soon be ready to publish.

By the surveys we find the most successful farmers, the most successful with small capital, with small area, with poor soil, or under other conditions. This department is making a continued study of such farms.

Believing that the survey method could be used for studying the cost of production of farm products, a study of the cost of producing milk was started in 1912 in Delaware county. In order to check the work the same farms were again visited in 1913. The results of this study will soon be ready for publication. In 1913 the cost of producing potatoes was studied by this method. This work was done in cooperation with the Department of Farm Crops, that department studying methods of potato production.

ACCURACY OF SURVEY METHODS

The accuracy of the work depends primarily on the enumerator and on how the questions are asked, not on the farmers. There are many methods of checking the work. If a farmer gives his yield and price of apples and total receipts, it is easy to check the results and see how accurate they are. If he gives the number of cows on hand now, the number a year ago, the number sold, the number bought, the number that died, and the number of heifers that became cows, the results may be checked at once. The number last year, plus cows purchased and heifers that became cows, less deaths and sales, gives the number now on hand. If this does not agree with the farmer's figure, the error is at once checked. The enumerator soon learns the cost of threshing each kind of grain. The total yield of grain and the threshing bill can then be checked. Similarly there are methods of checking almost every point on the record.

Another point in accuracy is that when large numbers are used the average will be more accurate than the individual records. The probable

error of the average of a series of observations is expressed by the mathematical formula

$$0.6745\sqrt{\frac{\Sigma D^2}{n(n-1)}}$$

Σ stands for the sum of the squares of the differences of each separate measurement from the mean of all the measurements. n is the number of measurements.

The accuracy of the result varies approximately as the square root of the number of measurements. Other things being equal, four measurements are twice as accurate as one.

The nearer the results are alike, the more accurate they may be expected to be. A few diverse results mean very little. The more the results vary, the more records are needed in order to secure accuracy. Accuracy may be obtained by many approximate measurements or by a smaller number of very accurate measurements.

But when we deal with living things or with farming as a business, however accurate our measurements, we must have many of them in order to obtain reliable results even if the individual results are absolutely correct. If we want to know how much an average cow weighs, we can never find out by the most accurate weighing of a single cow. She may not be an average cow. The weight of a thousand cows, each weighed to the nearest 100 pounds, would be infinitely more reliable than the weight of a single cow that was accurate to the nearest milligram.

If we kept the most accurate cost accounts on fifty farms, the results would be much less reliable than survey figures from one thousand farms. The danger of error from not having typical farms is greater than the errors in individual records when careful survey work is done.

In a survey in New Hampshire 135 farmers were asked to estimate the amount that they received from the sale of milk during the past year. These figures were compared with the actual payments made by the creameries. The total of the estimates was almost exactly correct, the error being only .00$\frac{3}{4}$ of 1 per cent. The amount of milk sold was estimated by 79 farmers. The error of the total was less than one per cent.[2]

At the Graduate School of Agriculture in 1912, the writer had 82 persons guess on the length of a stick that was held up before them. The guesses varied from 3 feet 6 inches to 5 feet 2 inches. They averaged 52.01 inches. Careful measurement showed the stick to be 50.8 inches long. The average of the guesses gave an error of 2 per cent. The writer handed the stick to each of two stenographers with the request that it be measured. Neither of these results was as accurate as the average guess.

But there is no excuse for great inaccuracy in survey records. *The*

[2] W. J. Spillman. Proceedings of the Society for the Promotion of Agricultural Science, 1912, page 111.

accuracy depends primarily on the person who asks the questions. The labor income on each record should be as accurate as the results of plot tests of fertilizers.

Errors due to prejudice on the part of farmers or of the enumerator are of an entirely different class. They are not compensating errors. If farmers are asked the value of their farms by an assessor, the results are not likely to be accurate. In our work we are very careful that all information shall be confidential. One neighbor is not told of another neighbor's figures. Confidence is soon secured, so that danger of boasting or the reverse is eliminated. A farmer cannot easily inflate his crop yields and make them agree with his threshing bill or the size of his silo.

It is desirable that the enumerator be searching for the truth rather than for facts to prove a theory. If he is prejudiced, he must be sure that he does not let his opinions affect his figures.

METHODS OF CONDUCTING STATISTICAL SURVEYS

Definite object necessary. Before starting a survey of any kind one should make up his mind just what he proposes to study. This advice should be unnecessary, but some haphazard studies that have been made indicate the lack of a definite aim.

Too much should not be attempted. Before starting survey work one should decide on the absolutely essential facts that he desires to obtain. He should be very slow to add any other points. For instance, if labor income is desired, two inventories and the receipts and expenses for a year are essential. Only a very few more things should be added. Almost invariably the blanks sent to the writer for criticism attempt too much. For instance, one college evidently desired to get labor income and to study the live-stock and buildings in great detail. For each individual horse, cow, sheep, and hog, the blank called for age, weight, color, registration, breed, grade, scrub, sound or unsound, if blemished the cause, cost, value. Each barn was to be described as to kind, size, area of windows, kind of stanchions or ties, size of stalls, floor, walls, ceilings. Similar detailed questions were included about the house, milk room, silo, and other matters. Many of the questions could not have been answered. As a result of trying to get too much, some of the essential facts for labor income were omitted. The work attempted would fail entirely, as exactly such attempts have failed many times before. If so much information is desired, it should be obtained in at least two, and probably three, separate studies: One to get labor income, one to study the details about buildings, and one to study details about live-stock. Even if it were possible for the investigator to keep so many things in mind, it would take too much of the farmer's time and energy to answer so many questions at one time.

Every record should be completely filled. A common error made by persons who are not experienced is to leave some spaces blank because of difficulty in getting the information. Such records are not only useless, but they throw all the other records in doubt. A blank may then mean 0 on one record and an unknown amount on another record. Every blank that applies to the farm should be filled. The best way of handling it is to get as accurate an estimate as possible while on the farm. If it is not possible to get an estimate, then the entire record should be thrown away. Partly filled records are much worse than useless.

Supervision of the work. Careful supervision of the work is necessary. Occasionally some valuable information is gathered by mail or by students who have been sent out alone. But ordinarily the man who is in charge of the work and who is to write it up should be in the field. After much experience has been gained, it is sometimes possible to direct work from an office, but certainly not for the first year.

Typical region and year. Agricultural surveys should be for a region that is an agricultural unit rather than a political unit.

The year for which data are obtained should be a normal year, unless results are to be obtained for several consecutive years.

If one is studying a crop that varies greatly in yield or in price, as in the cases of apples and potatoes, the results should be obtained for several years if possible.

The time of year chosen for the work should ordinarily be when the farmers are not very busy. August and the early part of September are usually good times in the latitude of Chicago.

If the record calls for a year's business, attention should be given to the normal time for the ending of a year's work. This is usually at the time when tenants move.

Number of records necessary. A thousand records are a good number for use. In some cases five hundred will do. Some of the best results of survey work are those that come when the records are sorted two or more times. For instance, in an orchard survey in New York, it is desirable to sort the records by the time that the orchard has been tilled or has been in sod, and subsort by the method of spraying. Sometimes more subsorts are desirable. We can then see the results when orchards are tilled and sprayed a given number of times.

Similarly, in a farm-management survey it is desirable to sort dairy farms by area in crops, subsort by yield of crops, and subsort again by receipts per cow. If there are three groups in each of the sorts, there would be twenty-seven groups when sorted three times.

It usually requires at least 20 records in a group to get reliable results. With much less than 20 records in a group a single farm that is unusual has too great an effect on the average.

How to ask questions. Questions should be asked in terms in which the farmer thinks. Questions should not call for computations by the farmer. To ask any one his total expenses is not likely to result in an accurate reply. But most farmers can tell the threshing bill fairly accurately. The veterinary bill, the horseshoeing bill, the labor bill, and the like, can each be fairly accurately secured if asked in detail. A long list of such questions is usually more easily and quickly answered than the single question, and is very much more accurate.

If one desires to get the time required for growing a crop, it is better to ask the time for each operation for a particular field in a given year rather than to ask how many acres are plowed in a day, how many are cultivated, and similar questions. If the questions apply to a particular field, they will be specific. If general questions are asked, they may not fit a field of that size, soil, or other conditions. If a farmer is asked how many days it took him to plow a particular 20-acre field, the time is likely to be longer than the result if he is asked how many acres he plows in a day. The latter statement is not likely to include lost time that comes from unforeseen delays.

When a new kind of work is started, a blank should be prepared and tried for some time before it is printed. Or some copies may be printed and the form held for changes before the final printing. It is certain to need many changes.

The field party. It is usually desirable to have at least two persons work together. The discussions that come up are of great help. Survey work is not easy work and it is well to have some one for companionship.

If considerable work is to be done a party of five or seven is best. The person in charge can then stay at the boarding place and spend all his time in checking records. It is usually most economical to have two persons go out together with one horse. One man and the horse stop at the first house, while the second man goes on to the next place. In this way almost as much is done as if each man had a horse.

Only those persons who have grown up on farms or who have lived on farms long enough to be thoroughly familiar with farm work are likely to succeed in survey work. For statistical work it is also necessary that one be unusually accurate and reasonably quick in the use of figures.

Those who take records should be farm-reared boys, so that they know the details of farming and understand farmers. As one man expressed it, they must know "farm etiquette." They should not be the kind who stand around with their hands in their pockets while the farmer unhitches. Only by years of farm experience can one learn the details of farming that he needs to know if his work is to be accurate. In some cases one of the men should take the farmer's place at work while the other man

gets his record. This is particularly necessary if threshing or other important operations are going on.

Before going into the field the men should be given considerable practice in filling out and studying the blanks that are to be used. The person who is to interpret the results should do enough work to make him entirely familiar with all the conditions. It will not do to send some one out to get records for a man in an office to study.

The location of every farm visited should be marked on the map and numbered. This makes it possible to go back and study the same farm or field ten or one hundred years from now. (See Bulletin 226 of this station, page 243.)

All records should be copied every night and should be checked by another person. Any errors or omissions can then be corrected either by telephone or by going back to the farmer. The copying and checking of records is of the utmost importance. If the work is not done in this way, the extra cost of tabulating results may equal the cost of the field work.

In the farm-management surveys where data for the calculation of the labor income are obtained, one man can get about four records a day in a well-settled community. About six records a day can be taken in orchard surveys. In either case this calls for night work, copying records until bedtime.

STUDYING THE DATA

Calculations and tabulations. After the records are brought to the office, the necessary calculations on each record are made, one at a time. One thing is calculated on all the records. A second person does the work again for a check. One point after another is calculated by one person and checked by another until the record is ready for tabulation.

After trying many methods we have decided that the most rapid and most accurate method of tabulating results is to have the figures read by one person and written by another. After each tabulation is complete, the transfer is checked by reading the figures again. The additions and other calculations are then made by one person and checked by another. The tabulations can be made with a pen much faster than with a typewriter.

Tabulation sheets that are ruled both ways save much time. Computations are made with non-listing adding machines.

In each tabulation the item by which the records are sorted should be tabulated. If farms are sorted by area, the area should be tabulated. This gives the average area for each of the groups.

An endless amount of care is needed in interpreting statistics. Even with such care mistakes are likely to creep in. In Bulletin 295 of this station the writer concluded that the distribution of capital was nearly

the same on small and on large farms, the percentages in real estate, machinery, and live-stock being about the same. More data on the subject indicate that, while the percentage in real estate is about the same, yet this needs further analysis. The percentage in buildings is high and the percentage in land is low on the small farms. In the same bulletin the conclusion was reached that the more successful dairymen usually raise their cows. This is in accord with the common prejudiced statement that such a practice is necessary. More extended study of the question indicates that some of the more successful men buy and some raise their cows, but that on the whole the more successful men do more buying and selling than the average. They are less likely to keep a poor cow, even if she was raised at home.

Sort by the cause, not by the effect. If one wishes to determine what factors affect labor income he should sort by the various factors, not by labor income. This principle is very important. If we want to know what factors affect crop yield, we should sort by the factors that we think may have an influence, not by crop yield. Many persons are making mistakes in this matter. We made this mistake in our first bulletin, No. 271. Suppose that we sort by labor income in order to see what factors affect it, and then take the most successful and the least successful farms for comparison. We shall probably find that the difference in area in the two groups is not striking. It is very difficult to make a large loss without having a large farm. The large losses and the large profits of necessity include many of the larger places.

One circular[3] that makes a comparison by this erroneous method gives the following results:

100 most profitable farms, 203 acres, 50 tillable.
100 least profitable farms, 182 acres, 44 tillable.
428 average farms, 174 acres, 43 tillable.

The conclusion is drawn that "the small difference in acreage does not seem to offer an adequate explanation for the great difference in income."

It is just as necessary to have a good-sized business in order to make a large loss as it is in order to make a large profit. Inevitably the big losses are made on big farms. In all tabulations of large numbers of farms, the least profitable farms have larger capital and larger area than do farms of small profits. After we pass the point of no profits, farms get larger whichever way we go. The figures quoted above show this point, for both the profitable and the unprofitable farms are larger and have more capital than the average. (See also Bulletin 41 of the U. S. Department of Agriculture, pages 17–18.)

Sorting the farms by the above method resulted in wrong conclusions

[3] U. S. Dept. Agr., Bureau of Plant Industry. Circ. 128, page 5.

as to the importance of area and capital. But when the same farms were sorted by tillable area, the 100 having the largest tillable area had an average labor income of $311, while the 100 having the smallest tillable area had an average labor income of $190 (page 5 of circular cited above). Here is an increase in labor income of 60 per cent due to larger size. This very striking difference shows the importance of size of farm. Size is not the only important factor. Crop yields, and returns per cow, are some of the other most important factors.

The following results from Tompkins county, New York, show the point:

18 least profitable farms, average area 137 acres.

25 most profitable farms, average area 176 acres.

From this the erroneous conclusion might be drawn that the areas are not strikingly different, and hence area is not important. But let us sort by area:

30 smallest farms, average labor income $168.

34 largest farms, average labor income $946.

Here is a contrast that is unmistakable. Of course a full study of the intermediate sizes and of the variations in labor income with each size is necessary. Such a study is given in Bulletin 295 of this station.

When we sort by labor income, we usually find that the crop yields on the most successful farms are not strikingly different from the average; but when we sort by crop yields per acre, we see that yield per acre is an important factor affecting profits.

One farm may be successful in spite of poor crops, because it has a large area of crops and has good animals. Another farm may be very successful with a smaller area of crops that yield better. Another may have a large area of good crops and have poor cows, and yet succeed very well indeed. If all these are averaged together, each one tends to obscure the reason for the success of the other. In Jefferson county, New York, out of over 600 farms the 97 largest farms made much more than the average. The 97 with best crops made more than the average. The 97 with best returns per cow also made much more than the average. But these factors are only slightly correlated. The farmers with best crops are only slightly more likely to have the good cows than are the average. There was not a single farmer out of the 600 who came in the best sixth as to cows, crops, and size of farm. This will be more fully explained in a forthcoming bulletin.

An illustration from a subject on which all will agree may make this point clearer. Probably every one will agree that height has considerable to do with weight. Out of 337 students in farm management, the 30 heaviest ones were only 7 per cent taller than the 30 lightest. One might

conclude that height has little to do with weight. But the 30 tallest students were 22 per cent heavier than the 30 shortest. Some persons are heavy in spite of being short, not because they are short. Height is a very important factor affecting weight, but it is not the only factor. Ordinarily, if we sort by weight the factors are confused, but if we sort by height we eliminate other factors to some extent. As mentioned in the next paragraph, we must study correlated factors before we can be sure of our results.

Correlated factors. In every tabulation one must see that the differences are not due to some other correlated factor. For instance, if the farms are sorted by number of horses or work animals, the ones with the largest number will be seen to make much better profits. One might recommend that farmers keep more horses. But the small farmer does not have work enough to keep his present supply of horses busy. The real explanation is that fair-sized farms pay better than small ones. These farms have more horses, but have fewer horses for their area. In each tabulation the most important factors that influence profits should be tabulated in order to see how much weight should be given to the results obtained. The results may be due to a correlated factor.

Averaging averages. Ordinarily an average should be obtained from original totals rather than by averaging averages. If we desire to consider each farm as a unit, then the average of averages is correct.

The average receipts per cow for a region is not the average of the average for each farm. The cow, not the farm, is the unit. Farms with few cows usually have lower receipts per cow than do those with many cows. If one farm keeps 5 cows and receives $50 per cow and another farm keeps 10 cows and receives $100 per cow, the correct average receipt per cow is $83 — not the average of the two farms, but the average of the 15 cows. In making tabulations, the original totals should be used when such an average is desired.

Sometimes the average of averages is correct. If we are dealing with farms having a certain quality of cows or certain receipts per cow, then the farm becomes the unit. The figures that gives the average quality of the dairy business for the two farms given above is $75.

Average and variation. In every case the variations, as well as the average, must be studied if we are to fully understand the facts. The average small farm makes very little, but how many small farms make $1,000? What is the upper and the lower limit with each size? (See tables 27, 28, and 29, Bulletin 295 of this station.)

Publication of least changeable data. The number of dollars that it costs to grow an acre of potatoes means very little. The important data are the hours of man and horse labor used, the pounds of paris green,

the bushels of seed, and the like The cost to feed a cow means very little, but the pounds of each kind of feed are important. When prices change, such data are still of value. Such data are also of value in other States.

Extension work. The surveys find the facts as to farming. The logical next step is to do extension work, both with the individual farmers and by publications and lectures.

REFERENCES

The survey idea in country-life work. L. H. Bailey. York State Rural Problems, I, pages 238–261.

Study of farm practice versus field experiments. W. J. Spillman. Proceedings of the Society for the Promotion of Agricultural Science, 1912, pages 103–113.

Apple orchard surveys. Cornell Univ. Agr. Exp. Sta. Bulletins 226, 229, 262, 307.

Agricultural surveys. Cornell Univ. Agr. Exp. Sta. Bulletin 295. U. S. Dept. Agr., Bur. Plant Indus. Circulars 75 and 128. U. S. Dept. Agr. Bulletin 41.

Rural (church) surveys. Publications of the Board of Home Missions of the Presbyterian Church.

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THE COLLEGE OF AGRICULTURE

Department of Poultry Husbandry

A CONTINUED STUDY OF CONSTITUTIONAL VIGOR IN POULTRY

Under the direction of
JAMES E. RICE

Offspring from late selection: upper, strong; lower, weak

By C. A. ROGERS

ITHACA, NEW YORK
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A CONTINUED STUDY OF CONSTITUTIONAL VIGOR IN POULTRY[1]

C. A. ROGERS

(*Received for publication March 6, 1914*)

The selection and care of two fall-selected White Leghorn flocks is described in Bulletin 318 of this station. Work has been continued with the progeny of these flocks, the results of which are here presented. For convenience of study the data for the later work are divided into two parts: in the first part are given the results of the work in the third year, which was with two pens of yearling hens and four pens of pullets; the second part contains a summary of all the strong and the weak flocks, comprising the two original fall-selected flocks and all their progeny.

The principal reason for continuing the work with the fall-selected flocks was because in their pullet year the progeny of the original flocks reversed the order in egg production. These fowls — flocks 11 (strong) and 13 (weak) in the work described in Bulletin 318 — gave an average egg production in their pullet year of 32.3 per cent for the strong flock and 33.6 per cent for the weak flock. In the other two comparisons the production was much greater for the strong flocks: strong flock 20, White Leghorns, giving an average production of 38.6 per cent while weak flock 22 gave only 34.8 per cent; and strong flock 12, Barred Plymouth Rocks, giving an average production of 34.2 per cent while weak flock 14 gave only 24.6 per cent.

The result in favor of weak flock 13 was very unexpected and was difficult to explain, especially since the progeny from the strong pen were so much heavier and better developed than the progeny from the weak pen, as is shown in Fig. 47. It was also thought that the selection of the parents was even more of an advantage in favor of strong flock 11 than in either of the other two comparisons.

The interest lay in finding whether this weak flock, which outclassed the comparison strong flock in the first year, would be able to do so in the second year; and also whether the weak flock could produce progeny which would outclass that from the strong flock, especially since the weak flock was made up of fowls that looked constitutionally unfit but seemed to have an inherent tendency to lay.

DATA FOR PROGENY OF ORIGINAL FLOCKS

The first part of this bulletin presents the results obtained with two pens of yearlings and four pens of pullets. All the fowls are White Leghorns. The yearling hens, in pens 76 and 77, are the fowls that were

[1] W. S. Lyon had general care of the flocks in the experiments discussed in this bulletin.

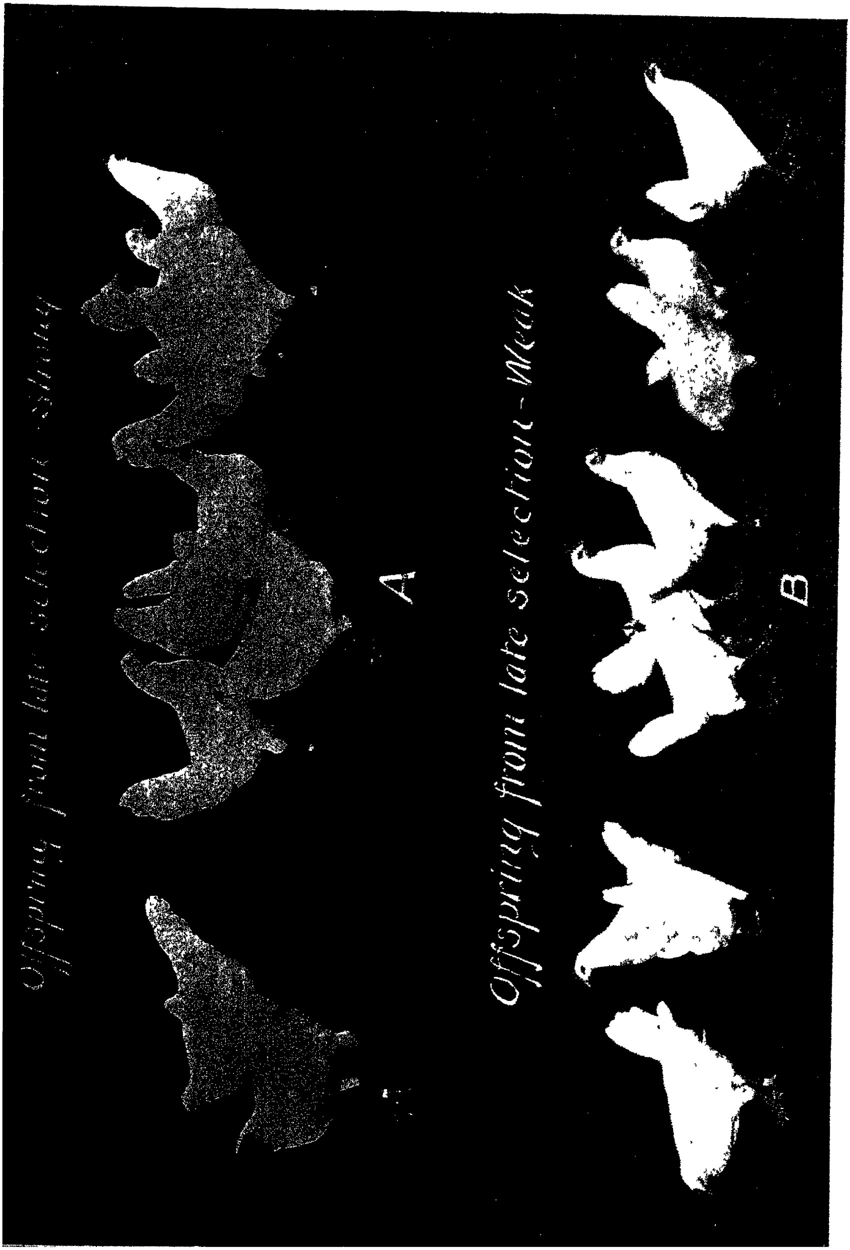

FIG. 47.— *The pullets in group A were hatched from the strong flock of late selection No. 76; those in group B came from the weak flock of late selection No. 75. These pullets were known as flocks 11 and 13 during their first year, and 76 and 77 during their second year. The parents are shown in Fig. 49. Observe the differences in size and type of body and comb*

in pens 11 and 13 during the previous year. The pullet flocks 22 and 23 are the progeny of the hens in pens 76 and 75 in the earlier work, and flocks 69 and 70 are the progeny of the hens in pens 11 and 13.

These fowls were cared for in the same manner as were their parents. They were fed according to the Cornell ration and method of feeding,[2] with a few variations as follows: The grain ration consisted of equal parts by weight of cracked corn and wheat from November 9, 1909, until October 11, 1910; and of 2 parts cracked corn, 2 parts wheat, and 1 part oats, from October 12, 1910, to November 7, 1910. The mash ration consisted of 6 parts by weight of corn meal, 3 parts wheat bran, 6 parts wheat middlings, 5 parts meat scrap, and 1 part oil meal, from November 9, 1909, to February 1, 1910; from February 2 until November 7, 1910, an addition of 1 part alfalfa meal was included in the mash. Green cut bone was fed, in quantities of one half ounce to each hen every day, from November 9 until March 14, 1910, with a very few omissions. Either beets or cabbage were fed throughout the year, supplemented or supplanted at times by sprouted oats.

No further selection was made of the fowls in flocks 76 and 77 for their second year, all the fowls that survived the first year being retained. A slight selection was made in the four pullet flocks at the beginning. If more pullets matured in one flock than in the comparison flock, the poorest ones were discarded in order to make the number equal at the beginning in the strong and the weak pens. Usually a few more matured from the strong flocks, but as a rule the division was very even.

[2] Cornell rations for laying hens.— The following whole-grain mixture is fed morning and afternoon in a straw litter:

By weight (Winter)	By measure (Winter)	By weight (Summer)	By measure (Summer)
60 pounds wheat 60 pounds corn 30 pounds oats 30 pounds buckwheat	32 quarts wheat 36 quarts corn 30 quarts oats 20 quarts buckwheat	60 pounds wheat 60 pounds corn 30 pounds oats	32 quarts wheat 36 quarts corn 30 quarts oats

The following mash is fed dry in a hopper kept open during the afternoon only:

By weight (Winter and summer)	By measure (Winter and summer)
60 pounds corn meal 60 pounds wheat middlings 30 pounds wheat bran 10 pounds alfalfa meal 10 pounds oil meal 50 pounds beef scrap 1 pound salt	57 quarts corn meal 71 quarts wheat middlings 57 quarts wheat bran 20 quarts alfalfa meal 8 quarts oil meal 43 quarts beef scrap ½ quart salt

The fowls should eat about one half as much mash by weight as whole grain. Regulate the proportion of grain and ground feed by giving a light feeding of grain in the morning and about all that the fowls will consume at the afternoon feeding (in time to allow of their finding the grain before dark). In the case of pullets or fowls in heavy laying, restrict both night and morning feeding so as to induce heavy eating of dry mash, especially in the case of hens. This ration should be supplemented with beets, cabbage, sprouted oats, green clover, or other succulent food, unless the fowls are running on grass-covered range. Grit, cracked oyster shell, and charcoal should be accessible at all times. Green food should not be fed in a frozen condition. All feed and litter used should be strictly sweet, clean, and free from mustiness, mold, or decay. Serious losses frequently occur from disease, due to the fowls' taking into their bodies, through their intestinal tract or lungs, the spores of the fungus causing molds.

TABLE 1. FOOD CONSUMPTION PER HEN[1] (IN POUNDS)
(1909–1910)

	Yearling hens		Pullets							
							True average[2]		Difference	
	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak
Pen	76	77	22	23	69	70	22 and 69	23 and 70		
Average number of hens	5.17	5.70	25.00	24.67	20.00	19.90	22.50	22 29	0 21	......
Total quantity of food	84.46	89 75	78.54	74 64	78 87	71.80	78 68	73 37	5 31	......
Total quantity of food excluding grit and shell	82.68	85.95	75.34	71 37	75 58	69.00	75.44	70.31	5.13	......
Total quantity of food excluding grit, shell, and green food	62.42	67.92	66.48	61 97	65 52	58 91	66 04	60.61	5 43	......
Total whole and ground grain	56.33	60.21	58.18	55.09	57.46	51.65	57.85	53.57	4.28	......
Total whole grain	43.63	42.32	39.82	41.11	38 65	36.91	39.29	39.24	0 05	......
Total ground grain	12.70	17.89	18 36	13.98	18.81	14 74	18 56	14 33	4.23	......
Total meat scrap	3.79	5.51	5.63	4.18	5.65	4 84	5.64	4.47	1.17	......
Total grit and shell	1.78	3.80	3.20	3 27	3 29	2.80	3.24	3.06	0.18	......
Total green cut bone	2.30	2.20	2.67	2.70	2.41	2 42	2.55	2.57	.....	0.02
Total green food	20.26	18.03	8.86	9.40	10.06	10.09	9.40	9.70	.....	0 30
Percentage of whole grain in total food excluding grit, shell, and green food	69.9	62.3	59.9	66.3	59.0	62.7	59.5	64.7	.....	5.2
Percentage of ground grain in total food excluding grit, shell, and green food	20.3	26.3	27.6	22.6	28.7	25.0	28.1	23.6	4.5	.....
Percentage of meat scrap in total food excluding grit, shell, and green food	6.1	8.1	8.5	6 7	8.6	8.2	8.5	7.4	1.1	.....
Percentage of grit and shell in total food excluding green food	2.8	5.3	4.6	5.0	4.8	4.5	4.7	4.8	.....	0.1

[1] The males in the pen are considered in the average during the months in which they are in the pens.
[2] The true average in all tables is obtained by using the totals in the original data instead of the "per hen" data.

Food consumption

Certain differences and inconsistencies between the strong and the weak flocks are noticeable in Table 1. It is necessary to anticipate Table 4, giving the egg production, in order to compare these data. The yearling weak flock 77 consumed more food than did the yearling strong flock 76, but it also produced more eggs. In all the pullet pens the consumption of food and the production of eggs were greater for the strong flocks. The same general relation was found to be true in the first two years of this work. It would seem, therefore, that in this one instance the consumption, rather than the vitality, is correlated with egg production. Perhaps the weak flock 77 was really stronger than the strong flock 76; but to all appearance this was not the case.

The consumption of whole grain was about the same for all flocks, for that was fed by hand according to formulas. But the ground grain and the meat scrap were fed together and the fowls were allowed to help themselves. In the consumption of these materials the difference is in favor of the flocks that produced the largest number of eggs. This difference varied in the same way as did the total consumption.

The proportion of nutrients, shown in Table 2, is in inverse ratio to the percentage of ground grain and meat scrap in total food consumed. This is due to the fact that the ground grain and the meat scrap were much richer than the other food consumed, and to the further fact that the other foods were fed in standard amounts. By referring to tables 4 and 2 it is seen that those flocks that laid the most eggs — pens 77, 22, and 69 — had the lowest proportion of carbohydrates and fat. It is seen also that the proportion of protein to carbohydrates and fat consumed by the heaviest-producing flocks is less than for the others.

It is seen in Table 3 that in general the cost of food for each dozen eggs laid is less for the strong than for the weak flocks. The exact cost per dozen eggs laid is in inverse proportion to the total number of eggs laid. Flock 77 produced the greatest number of eggs, 160.18 per hen, at the lowest cost of food per dozen, 9.3 cents; and so on down to the poorest-laying flock, 76, which produced 99.81 eggs per hen at a food cost of 13.8 cents per dozen. The proportionate cost of food per dozen eggs laid tends to form the same inverse ratio to the food consumption, but in these comparisons there is some difference in the order of flocks. Again, in the number of pounds of food consumed for each dozen eggs laid, the heavier the laying the less was the consumption, with one exception. This exception was in the case of flock 77, which laid more eggs than did flock 69 but consumed slightly more food for each dozen eggs produced. This condition can probably be explained by the fact that flock 77 was made up of hens and flock 69 of pullets.

TABLE 2. TOTAL FOOD NUTRIENTS CONSUMED [1] (PER HEN)
(1909–1910)

	Yearling hens		Pullets							
							True average		Difference	
	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak
Pen	76	77	22	23	69	70	22 and 69	23 and 70		
Dry matter (pounds)	59.26	63.73	60.29	56.46	60.68	53.83	60.46	55.28	5.18	..
Protein (pounds)	8.94	10.51	10.21	8.87	10.15	8.45	10.18	8.68	1.50	..
Carbohydrates (pounds)	39.73	41.26	37.85	37.52	38.33	35.03	38.06	36.40	1.66	..
Fat (pounds) [2]	2.41	2.75	2.62	2.33	2.61	2.32	2.61	2.33	0.28	..
Ash, including grit and shell (pounds)	1.86	2.04	1.94	1.77	1.93	1.72	1.93	1.75	0.18	..
Food value of carbohydrates and fat in comparison with protein	5.05	4.51	4.28	4.82	4.35	4.76	4.32	4.80	.....	0.48

[1] The analyses used in computing this table are the same as were used in Bulletin 318 and are as follows:

Food	Dry matter	Protein	Carbohydrates	Fat	Ash
Corn	89.4	7.9	66.7	4.3	1.5
Wheat	89.5	10.2	69.2	1.7	1.8
Oats	89.0	9.2	47.3	4.2	3.0
Buckwheat	87.4	7.7	49.2	1.8	2.0
Corn meal	88.0	7.9	65.3	2.9	1.4
Wheat bran	88.1	12.2	39.2	2.7	5.8
Wheat middlings	87.9	12.8	53.0	3.4	3.3
Oil meal	90.8	29.3	32.7	7.0	5.7
Alfalfa meal	91.6	11.0	39.6	1.2	7.4
Meat scrap	88.3	66.2	0.3	13.7	4.1
Blood meal	91.5	84.4	0.0	2.5	4.7
Beets	9.1	1.1	5.4	0.1	1.1
Cabbage	15.3	1.8	8.2	0.4	1.4
Turnips	9.5	0.7	5.3	0.2	0.8
Green bone	65.8	18.0	43.0	0.0	11.5
Oyster shell	100.0	0.0	0.0	0.0	100.0
Grit	100.0	0.0	0.0	0.0	100.0
Sprouted oats	26.1	3.5	15.2	1.1	1.5

[2] The quantity of fat is multiplied by 2¼ in computing the food value.

TABLE 3. COST OF PRODUCING EGGS (PER HEN)
(1909–1910)

	Yearling hens		Pullets							
							True average		Difference	
	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak
Pen	76	77	22	23	69	70	22 and 69	23 and 70		
Cost of total food for each dozen eggs laid.	$0.138	$0.093	$0.104	$0.118	$0 096	$0.124	$0 100	$0.120	.....	$0 020
Cost of total food minus value of gain in weight for each dozen eggs laid	$0.135	$0.090	$0 096	$0.111	$0 087	$0.112	$0 092	$0 111	.....	$0 019
Pounds of total food consumed for each dozen eggs laid	10.151	6.723	6 932	7.966	6.491	8 409	6.725	8 153	.....	1 428

Egg production

In Table 4 is shown the percentage of egg production for each month of the year, and the total number of eggs produced per hen for the year. In addition to showing that the percentage of production is consistently in favor of the strong flocks — with the exception of weak flock 77 — the table shows what can be expected in the way of production during the average months of the year.

It is interesting to note that weak flock 77 greatly exceeded strong flock 76 in its second year of production, as the same fowls did in their pullet year. The fact that there were only seven and six hens, respectively, in these flocks probably aided in making possible so great a difference. The six hens in strong flock 76 laid about the usual number of eggs for yearling hens, while the seven hens in weak flock 77 laid a much greater number of eggs than is ordinarily expected even of pullets. This is graphically illustrated in Fig. 48.

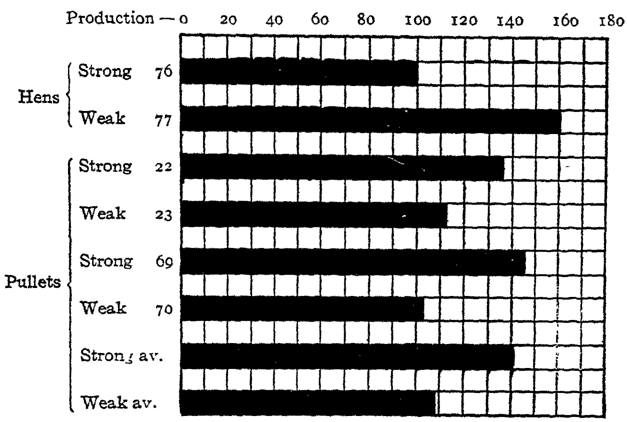

FIG. 48.— *The comparative production of eggs of the average individual in each flock. The average of the strong and of the weak includes only the pullet flocks*

This is a case of the unexpected happening, therefore a comparison with other flocks containing sisters and daughters of these fowls is interesting. Strong flock 11 (76 in the second year) and weak flock 13 (77 in the second year) produced the pullets in strong flock 69 and weak flock 70, respectively. The parents of flocks 11 and 13 produced strong flock 22 and weak flock 23, respectively. In both comparisons of the pullets the strong flocks have outclassed the weak flocks. The results in production of the progeny of these flocks, then, would seem to show that weak flock 77 was an exception and that it contained a few exceptional layers which greatly affected the average of the pen containing only seven fowls. The same method of selection was used in all cases, no special selection having been made after the first year except that each set of pullet flocks was culled to an equal number. This method afforded no particular advantage

TABLE 4. PERCENTAGE OF EGG PRODUCTION BY PERIODS (1909–1910)

Period	Date	Yearling hens		Pullets							
		Strong	Weak	Strong	Weak	Strong	Weak	True average		Difference	
								Strong	Weak	Strong	Weak
		Pen 76	Pen 77	Pen 22	Pen 23	Pen 69	Pen 70	Pens 22 and 69	Pens 23 and 70		
1	Nov. 9 to Dec. 7	2.3	3.5	9.0	19.7	2 6	0.4	6.2	11.1	....	4 9
2	Dec. 8 to Jan. 4	4 7	6.8	22.1	19.4	16 9	5.0	19.8	13.0	6 8	
3	Jan. 5 to Feb. 1	8.9	25.5	29.7	20 1	26.0	11 6	28.1	16.3	11.8	
4	Feb. 2 to March 1	41 0	52 3	40.4	27 7	38 0	32 3	39 3	29.8	9.5	
5	March 2 to March 29	50.5	74.4	56.4	57.0	60.5	55.1	59.0	56.2	2 8	.
6	March 30 to April 26	56 4	82 1	68.0	61 0	70 0	61 6	68 8	61.2	7.6	. .
7	April 27 to May 24	49 2	77 9	64.2	56.1	70 0	61 0	66.8	58.3	8.5	. . .
8	May 25 to June 21	45 0	70.0	52 4	40 7	57 6	46 9	54.7	43 5	11 2	.
9	June 22 to July 18	32 1	60 7	44.8	36 7	56 9	42 8	50 2	39.4	10 8	.
10	July 19 to Aug. 16	25 8	66 4	46.8	24 1	48.3	26.7	47.5	25 3	22 2	
11	Aug. 17 to Sept. 13	16.9	44 2	30.8	24 1	43 2	17 5	36 4	21.1	15 3	.
12	Sept. 14 to Oct. 11	13 3	17 1	15.4	9 8	21 6	2.8	18.1	6 7	11 4	
13	Oct. 12 to Nov. 8	0.8	0.0	3.9	2 5	8 5	0 0	5 9	1 3	4 6	
Average		27 4	44.0	37 4	30.9	40 1	28 1	38.6	29 7	8 9	
Total number of eggs produced (per hen)		99.81	160.18	136.00	112 44	145 80	102 46	140 36	107 99	32 37	.

to either flock, since the same number of eggs were incubated in each case and the chicks were brooded alike. If more chicks survived from one flock than from another, it was a just credit to that flock.

Hatching record

Only a relatively small number of eggs were incubated, especially in pens 76 and 77 where there were only six and seven hens, respectively. The fertility in all pens was high but the percentage of eggs that hatched was variable. It is generally assumed that fowls in good laying condition are in healthy physical condition also, which should insure the necessary strength in an egg to make it hatch if fertilized and properly incubated. In two of the comparisons in Table 5, however, such a result is not shown. Strong pen 76 greatly exceeded weak pen 77 in the percentage of chicks hatched, whereas flock 77 exceeded flock 76 in egg production, especially during the hatching period. Also, weak flock 23 greatly exceeded strong flock 22 in percentage of chickens hatched, while the rank in egg production was just the reverse. Strong flock 69 both outlaid and outhatched weak flock 70.

In weight of eggs set there was not much difference between the strong and the weak flocks, or between yearling hens and pullets.

In general the mortality among the chicks varied in proportion to the size of the hatch. In each comparison the eggs that hatched better produced a larger proportion of chickens that lived beyond the critical period of the first six weeks. The advantage in low mortality was with the strong flocks, with the exception of flock 23.

Financial statement

The financial statement given in Table 6 considers only cost of food, gain in weight, value of eggs, and loss of stock by death. It does not take into account interest on the money invested, difference in inventory value, cost of labor, value of litter, or value of manure. Since the latter factors remain essentially the same, the financial statement may be considered as near a true comparison of the relative profits of the different flocks as it is possible to make.

Naturally the greatest variation is in the value of eggs produced. There is a much less marked variation in the cost of food. The curve of the latter variation is much the same as that for the value of eggs produced. The balance profit in the case of the pullets is decidedly in favor of the strong flocks; in the comparison of the yearlings it is in favor of that weak flock which has been the exceptional flock throughout this study. This flock 77, of yearling hens, produced higher value in eggs than did any of the pullet flocks. Its greater consumption of food, however, placed it second to pullet flock 69 in actual balance profit.

TABLE 5. HATCHING RECORD
(1909–1910)

	Yearling hens		Pullets							
							True average		Difference	
	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak
Pen	76	77	22	23	69	70	22 and 69	23 and 70		
Number of eggs set	125	125	250	250	250	250	500	500	.	
Percentage of fertile eggs	96.0	93.6	98.0	98.0	98.4	98.8	98.2	98.4		0.2
Percentage of eggs hatched in fertile eggs	74.1	63.2	39.3	75.5	67.0	58.7	53.1	67.0	.	13.9
Percentage of eggs hatched in number set	71.1	59.2	38.5	74.0	65.9	57.9	52.1	65.9	.	13.8
Average weight of eggs set (pounds)	0.1210	0.1205	0.1212	0.1237	0.1182	0.1173	0.1197	0.1205		0.0008
Average weight of chicks hatched (pounds)	0.0661	0.0743	0.0833	0.0843	0.0747	0.0818	0.0774	0.0834	..	0.0060
Percentage mortality of chicks to six weeks of age	13.9	18.3	16.7	11.3	13.5	20.9	14.5	15.4	.....	0.9

TABLE 6. FINANCIAL STATEMENT (PER HEN)
(1909–1910)

	Yearling hens		Pullets							
							True average		Difference	
	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak
Pen	76	77	22	23	69	70	22 and 69	23 and 70		
Income:										
Value of eggs	$2.424	$4 061	$3 615	$2 987	$3 796	$2 527	$3 701	$2.802	$0.899	...
Value of gain in weight	0 018	0.036	0 082	0 070	0 104	0.103	0.092	0.085	0 007	...
Outgo:										
Cost of food	1 152	1.241	1 174	1 106	1.166	1.059	1.170	1.084	0 086	...
Cost of loss of stock	0.210	0 211	0 000	0 022	0.000	0 018	0 000	0.020	..	0 020
Total income	2 442	4 097	3 697	3 057	3 900	2 630	3.793	2.887	0.906	...
Total outgo	1.362	1 452	1 174	1 128	1 166	1.077	1.170	1.104	0 066	.....
Balance profit	1.080	2 645	2 523	1 929	2.734	1.553	2 623	1.783	0.840	.....

SUMMARY OF ALL FLOCKS

In experimentation of this kind there are often unexpected, rather than inexplainable, variations which make conclusive deductions difficult, if not altogether impossible. Therefore it becomes necessary to repeat or to continue the work with a large number of fowls and to cover a number of years, in order to get data sufficient to offset or to submerge the effect of the exceptional case. Consequently the true averages of large numbers of fowls, divided into flocks and carried through several years, should be considered, as furnishing the more nearly correct data and allowing more positive conclusions to be drawn.

In this part of the bulletin the original fall-selected White Leghorn flocks — 76 (strong) and 75 (weak)— and all the flocks originating from them have been averaged together. The original flocks are shown in Fig. 49. The averages are the true averages, which have been obtained by using the total number of fowls and the total number of eggs laid, the total food consumed, and analogous data, not by averaging the "per hen" results of each flock. The latter method would give an entirely different result and would allow of a small flock's influencing the result quite as much as would a flock with a much larger number of individuals.

Food consumption

The strong fowls consumed more food than did the weak fowls, as might be expected. This is shown in Table 7. The most conspicuous difference is in consumption of ground grain and meat scrap. Both weak and strong fowls were fed the same amount of grain, but the strong fowls were able to consume more of the ground food.

The reason why the percentage consumption of whole grain in total food excluding grit, shell, and green food is greater for the weak flocks, is because the whole grain was fed alike to both strong and weak flocks and the total consumption of other food was less for the weak flocks than for the strong. The strong fowls consumed a larger percentage of ground food and meat scrap. The percentage consumption of grit and shell was practically equal.

The total quantity of food nutrients (Table 8) was obtained by using the same analyses as are given in connection with Table 2. The number of pounds of carbohydrates and fat to each pound of protein, or the nutritive ratio, is 1 to 4.68 for the strong and 1 to 5.08 for the weak flocks. The ratio of 1 to 4.68 is very near that found by Professor Wheeler, of the New York (Geneva) Agricultural Experiment Station, to be the right proportion to properly balance the ration. The ratio that he recommends is 1 to 4.6.

A most interesting comparison is shown in Table 9. The number of pounds of dry matter consumed per pound of live weight averages the

FIG. 49.—*The two flocks of fall-selected pullets used in the first year of the experiment. These fowls were the parents or the grandparents of all the fowls used in the experiment described in this bulletin. A is strong flock 76 and B is weak flock 75*

same for both the strong and the weak fowls. There is a difference, however, between the strong and the weak flocks in the number of pounds of food consumed for each dozen eggs laid: the strong fowls required 7.68

TABLE 7. FOOD CONSUMPTION PER HEN (IN POUNDS)
(Average for all years)

	True average		Difference	
	Strong	Weak	Strong	Weak
Pens	76–76– 11–76– 22–69	75–75– 13–77– 23–70		
Total quantity of food	80 30	75 91	4.39	....
Total quantity of food excluding grit and shell	77 07	72.82	4.25	....
Total quantity of food excluding grit, shell, and green food	67.49	62.73	4.76	.....
Total whole and ground grain	60 16	56.58	3.58	....
Total whole grain	44 46	44 05	0 41	.....
Total ground grain	15 70	12 53	3.17	....
Total meat scrap	4 82	3.95	0.87	....
Total grit and shell	3 23	3.09	0.14	.. ...
Total green food	9.58	10.09	......	0.51
Percentage of whole grain in total food excluding grit, shell, and green food	65 9	70.2	.... ..	4.3
Percentage of ground grain in total food excluding grit, shell, and green food	23.3	20.0	3.3	....
Percentage of meat scrap in total food excluding grit, shell, and green food	7 1	6.3	0.8	....
Percentage of grit and shell in total food excluding green food	4 6	4 7	.... ..	0.1

TABLE 8. TOTAL FOOD NUTRIENTS CONSUMED (PER HEN)
(Average for all years)

	True average		Difference	
	Strong	Weak	Strong	Weak
Pens	76–76– 11–76– 22–69	75–75– 13–77– 23–70		
Dry matter (pounds)	61.73	56.93	4.80	....
Protein (pounds)	9.69	8.50	1.19	....
Carbohydrates (pounds)	39.50	37 72	1.78	....
Fat (pounds)	2 59	2.41	0.18	....
Ash, including grit and shell (pounds)	1.91	1.73	0.18	....
Food value of carbohydrates and fat in comparison with protein	4 68	5.08	......	0.40

pounds of food for every dozen eggs laid, while the weak flocks required 8.46 pounds of food. Consequently it cost the strong flocks less than it cost the weak to produce a dozen eggs, the exact difference being nearly one cent a dozen. When one considers the very limited selection of stock, this difference is really pronounced.

TABLE 9. CONSUMPTION, PRODUCTION, AND WEIGHT COMPARED
(Average for all years)

	True average		Difference	
	Strong	Weak	Strong	Weak
Pens	76-76-11-76-22-69	75-75-13-77-23-70		
Pounds of dry matter consumed per pound of live weight	17.68	17.68	......	....
Pounds of food consumed for each dozen eggs laid	7.68	8.46	......	0.78
Cost of food for each dozen eggs laid	$0.114	$0.123	......	$0.009

TABLE 10. PERCENTAGE OF EGG PRODUCTION BY PERIODS
(Average for all years)

Period	Date	True average		Difference	
		Strong	Weak	Strong	Weak
		Pens 76-76-11-76-22-69	Pens 75-75-13-77-23-70		
1	Nov. 24 to Dec. 22	8.8	9.0	......	0.2
2	Dec. 23 to Jan. 19	17.1	12.9	4.2	......
3	Jan. 20 to Feb. 16	23.6	18.4	5.2	......
4	Feb. 17 to March 16	43.8	38.4	5.4	......
5	March 17 to April 13	60.6	56.8	3.8	......
6	April 14 to May 11	65.6	58.4	7.2	......
7	May 12 to June 8	60.9	55.6	5.3	......
8	June 9 to July 6	48.0	41.8	6.2	......
9	July 7 to Aug. 3	41.0	37.1	3.9	......
10	Aug. 4 to Aug. 31	39.1	27.1	12.0	......
11	Sept. 1 to Sept. 28	25.6	19.8	5.8	......
12	Sept. 29 to Oct. 26	10.7	7.2	3.5	......
13	Oct. 27 to Nov. 22	3.9	0.9	3.0	......
Average		34.4	29.6	4.8	....
Total number of eggs produced (per hen)		125.36	107.61	17.75	....

Egg production

The egg production was consistently heavier in the strong flocks throughout each period of the year with the exception of the first period. The difference in the total number of eggs produced per hen amounted to 17.75 eggs. This is about $1\frac{1}{2}$ dozen eggs, worth probably 30 to 40 cents a dozen.

Hatching record

In the hatching record (Table 11) there is very little preference for either the strong or the weak flocks. The eggs from the weak flocks had a higher fertility and hatched more chicks. The average weight of the eggs set was greater in the weak flocks than in the strong, but the chicks from the strong flocks were heavier than those from the weak. This is directly the reverse of all our other experimental data, but can be readily accounted for by the fact that the eggs for incubation, and the chicks after hatching, were weighed as a whole and not individually. Apparently the large eggs from the strong flocks had a greater tendency to hatch than did the corresponding eggs from the weak flocks. Usually the chicks vary in weight according to the weight of the eggs. The mortality among the chicks was 23.15 per cent for the strong flocks and 19.64 per cent for the weak flocks.

TABLE 11. HATCHING RECORD
(Average for all years)

	True average		Difference	
	Strong	Weak	Strong	Weak
Pens	76–76– 11–76– 22–69	75–75– 13–77– 23–70		
Number of eggs set	1,446	1,305	141	......
Percentage of fertile eggs	89 4	91.4	......	2.0
Percentage of eggs hatched in fertile eggs	55.4	56.4	......	1.0
Percentage of eggs hatched in number set	49.6	51.5	......	1.9
Average weight of eggs set (pounds)	0 2081	0.2198	......	0.0117
Average weight of chicks hatched (pounds)	0.0906	0.0767	0.0139	......
Percentage mortality of chicks to six weeks of age	23.15	19.64	3.51	......

Mortality

The percentage mortality (Table 12) was obtained by adding together the total number of hens in each pen at the beginning of each year, and

dividing the total number of deaths occurring in all these years by this sum. There was a difference of 1.4 per cent mortality, in favor of the strong pens.

TABLE 12. MORTALITY RECORD
(Average for all years)

			Difference	
	Strong	Weak	Strong	Weak
Pens	76-76- 11-76- 22-69	75-75- 13-77- 23-70		
Total number of hens	108	104	4	....
Total number of deaths	12	13	......	1
Percentage mortality	11 1	12 5	.....	1.4

Financial statement

The pecuniary comparison of two flocks or methods is always the most vitally interesting. If a practice shows neither an immediate nor a future profit, the practical man will discard it. In the comparison of all the strong flocks with all the weak flocks (Table 13), the strong hens showed decidedly the more profitable returns. The actual difference in profit when all but fixed and equal charges are considered amounted to 40 cents a hen, or $400 for one thousand hens, in favor of the strong fowls.

TABLE 13. FINANCIAL STATEMENT (PER HEN)
(Average for all years)

	True average		Difference	
	Strong	Weak	Strong	Weak
Pens	76-76- 11-76- 22-69	75-75- 13-77- 23-70		
Income:				
Value of eggs	3.12	2.67	0.45	....
Value of gain in weight	0.07	0.06	0.01	... ...
Outgo:				
Cost of food	1.19	1.10	0.09	....
Cost of loss of stock	0.08	0.11	......	0.03
Total income	3.19	2.73	0.46	....
Total outgo	1.27	1.21	0.06	....
Balance profit	1.92	1.52	0.40	....

Forty cents is more than many weak hens are worth. It is an unusually high return for so small an amount of work at the start in separating the stronger from the weaker fowls.

If this is an illustration of what may be expected naturally from a rational separation of the strong and the weak fowls — and it probably is, since no radical selection was practiced — then it would seem that the resulting increase in profit would make it well worth while to keep the strong hens and dispose of the weak ones. The more pronounced the difference between the strong and the weak hens, the better is the policy of disposing of the latter.

CONCLUSIONS

1. The continued study of this subject confirms the conclusions drawn in previous bulletins.[3]

2. The selection of fowls for strong vitality, even though such selection be slight and exercised but once, increases the productive power of a flock.

3. One selection only is not sufficient to keep a flock consistently superior.

4. The selection of mature pullets is of more value than that of partly grown chickens.

5. Selection at the beginning of the second year is of equal importance with that in the first year.

6. The results from flocks 76 and 77 indicate that the heavier-laying hen is not necessarily the stronger hen at all times of the year; and that in selecting for breeding stock to produce a large number of chickens and capable pullets, the first essential is to select according to strength, with the expectation that hens so selected will usually be the most productive.

[3] Cornell Reading-Course for Farmers, No. 45, and Bulletin 318 of the Cornell University Agricultural Experiment Station.

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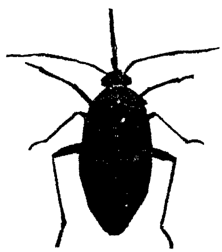
THE TARNISHED PLANT-BUG



BY C. R. CROSBY AND M. D. LEONARD

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THE TARNISHED PLANT-BUG

Lygus pratensis Linnaeus

Order, *Hemiptera* Family, *Capsidae*

C. R. Crosby and M. D. Leonard

More than seventy years ago T. W. Harris, in his classical work "Insects Injurious to Vegetation," called attention to an injury to dahlias, marigolds, asters, balsams, and potatoes caused by the feeding punctures of a small, obscurely marked, brownish plant-bug. This insect has since come to be known as the tarnished plant-bug. It has been recorded as causing serious injury to many other cultivated plants, especially chrysanthemums and strawberries, to the opening buds and blossoms of pear, plum, and apple, and to the terminal buds of peach nursery stock. In this country its habits and life history have been studied by Harris, Riley, Quaintance, Haseman, and others, and considerable attention has been given to devising methods for its control. In Europe much work has been done in describing and classifying the numerous variations in form and color exhibited by the adults of this species, and less attention has been given to its economic status. The literature relating to the insect is extensive, but the bulk of it consists of compiled accounts which merely repeat the statements of earlier authors. A list of all the articles that we have been able to find relating to the subject is placed at the end of this bulletin.

In 1894 the attention of the late Professor M. V. Slingerland was called to a serious injury to peach nursery stock at Newark and at Geneva, New York, which Professor Slingerland proved experimentally to have been caused by the feeding punctures of the tarnished plant-bug. In July, 1911, a block of peach nursery stock in a nursery near Rochester was examined, which had been severely injured in a similar manner. At the request of the owner, experimental work was begun in this nursery in May, 1912. A field laboratory was established and L. I. Snodgrass was stationed there until July 4. In 1913 the work was continued by David Gunn and M. D. Leonard, Mr. Gunn being in the field from June 17 to July 4 and Mr. Leonard from June 21 to August 29. Our hearty thanks are due to the owner of this nursery, who has placed at our disposal every facility for performing the work and who has in a large measure financed the undertaking. We regret that we are not at liberty to mention his name in this connection.

The work of Mr. Gunn deserves especial mention; his industry, perseverance, and enthusiasm under the most trying circumstances con-

tributed in a large measure to the proper performance of the experiments. We regret that other duties prevented him from remaining with us until the close of the season.

Notwithstanding all our efforts we have failed to devise any practical method of either destroying the bugs or preventing injury to the stock. In spite of this fact we believe a record of our failures may be of value to other workers by pointing out the extreme difficulty of the problem and by showing the inadequacy of many of the remedies proposed in the past. This bulletin is intended as a résumé of the existing knowledge of the tarnished plant-bug and as a record of our unsuccessful attempts to prevent its injury to peach nursery stock.

In the preparation of this bulletin we have made free use of Professor Slingerland's unpublished notes and a number of the illustrations are from photographs taken by him.[1] All the drawings were made by Miss Anna C. Stryke.

HISTORICAL

The tarnished plant-bug was first described by Linnaeus in 1746, in the first edition of a work on the fauna of Sweden. He gave to the insect the name *Cimex griseus* and stated that it occurs in meadows. In the second edition of this work, published in 1761, the name of the insect was given as *Cimex pratensis*. This name had already been used by Linnaeus in the tenth edition of his "Systema Naturae," 1758. The specific name is still retained, although the insect is now placed in the genus *Lygus*. The earlier European writers have from time to time placed this species in different genera, such as *Phytocoris*, *Lygaeus*, *Miris*, *Capsus*, and others.

In America the species was first described by Thomas Say in 1831, in a work on North American Hemiptera published at New Harmony, Indiana. Say gave to the species the name *Capsus oblineatus*. Specimens of the insect, however, had been collected in the United States more than thirty years previously, and were described by Palisot de Beauvais in a work on insects collected in Africa and in America between 1781 and 1797. This book was published in parts, from 1805 to 1821. Palisot de Beauvais named the species *lineolaris* and referred it doubtfully to the genus *Coreus*. He figured the insect, but unfortunately the name given in the explanation of the plate is *Coreus linearis*. Uhler and Packard were misled by this error. In 1841 Harris noted the identity of the species described by Say and by Palisot de Beauvais and adopted the name given by the latter, placing the species, however, in the genus *Phytocoris*. In the early American economic literature, therefore, the tarnished plant-bug is variously referred to as *Capsus oblineatus* and *Phytocoris lineolaris* or *P. linearis*.

[1] Figures 61 to 69, inclusive, are by Slingerland.

Owing to its extensive geographical distribution and wide range of variability, the tarnished plant-bug has been frequently described by entomologists as a new species. The names given, as well as the various generic combinations, are indicated in the following synonymical table:

1746 *Cimex griseus* Linnaeus
Fauna Svec., p. 208.
1758 *Cimex pratensis* Linnaeus
Systema naturae, 10th ed., p. 448.
1763 *Cimex umbellatarum* Scopoli
Ent. carniol., p. 133.
1778 (?) *Cimex rubecula* Goeze
Ent. beitr. **2:** 279.
1794 *Lygaeus pratensis* Fabricius
Ent. syst. **4:** 171.
1804 (?)*Lygaeus viridulus* Panzer
Schaeff. icon. **3:** 120.
1804 *Miris pratensis* Latreille
Hist. nat. **12:** 221.
1805 *Lygaeus umbellatarum* Panzer
Fauna ins. Germ., p. 93.
1805 *Coreus* (?) *lineolaris* Palisot de Beauvais
Ins. rec. Afr. et Amér., p. 187.
1807 *Lygaeus campestris* Fallen (not Linnaeus)
Mon. cim. Svec., p. 83.
1828 *Phytocoris campestris* Zetterstedt (not Linnaeus)
Fauna ins. lapp., p. 273.
1828 *Phytocoris pratensis* Zetterstedt
Fauna ins. lapp., p. 289.
1829 *Phytocoris campestris* Fallen (not Linnaeus)
Hemip. Suec., p. 91.
1831 *Capsus oblineatus* Say
Heterop. Hemip. N. Amer., p. 340. (Le Conte ed.)
1831 *Phytocoris campestris* Hahn (not Linnaeus)
Wanz. ins. **1:** 218.
1835 *Capsus gemellatus* Herrick-Schaeffer
Wanz ins. **3:** 81.
1837 *Phytocoris artemisiae* Schilling
Uebers. arbeit. u. verand. schles. Ges. vaterl. Kultur in 1836, p. 83.
1837 *Phytocoris adspersus* Schilling
Uebers. arbeit. u. verand. schles. Ges. vaterl. Kultur in 1836, p. 83.
1840 *Phytocoris campestris* Blanchard (not Linnaeus)
Hist. nat. ins. **3:** 138.
1840 *Phytocoris punctata* Zetterstedt
Ins. lapp. desc., p. 273.
1841 *Phytocoris lineolaris* Harris
Ins. inj. veg., p. 161.
1843 *Capsus pratensis* Meyer-Dür.
Verzeich. Schweis Rhyn., p. 99.
1845 *Phytocoris campestris* Kolenati (not Linnaeus)
Melet. ent. **2:** 118
1845 *Phytocoris alpina* Kolenati
Melet. ent. **2:** 120
1848 *Capsus punctatus* Sahlberg
Mon. Geoc., p. 110.
1848 *Capsus campestris* Sahlberg (not Linnaeus)
Mon. Geoc., p. 111.
1855 *Capsus* (*Deræocoris*) *gemellatus* Kirschbaum
Rhyn. Wiesb. **10:** 273.
1855 *Capsus* (*Deræocoris*) *pratensis* Kirschbaum
Rhyn. Wiesb. **10:** 273.

30

1855 *Capsus (Deræocoris) campestris* Kirschbaum (not Linnaeus)
Rhyn. Wiesb. **10**: 273.
1858 *Deræocoris pastinaceae* Stål
Stett. ent. zeitg. **19**: 186.
1858 *Deræocoris campestris* Stål (not Linnaeus)
Stett. ent. zeitg. **19**: 186.
1858 *Deræocoris pratensis* Stål
Stett. ent. zeitg. **19**: 186
1861 *Lygus pratensis* Fieber
Eur. Hemip., p. 273.
1861 *Lygus campestris* Fieber (not Linnaeus)
Eur. Hemip., p. 273.
1863 *Phytocoris linearis* Uhler
Flint ed. of Harris, Ins. inj. veg., p. 200. (Footnote.)
1871 *Capsus linearis* LeBaron
Nox. ins. Ill., 1st rept., p. 62.
1872 *Lygus lineolaris* Uhler
U. S. Geol. Hayden Survey, Montana, Prelim. rept., p. 413.
1872 *Lygus diffusus* Uhler
U. S. Geol. Hayden Survey, Wyoming, Prelim. rept., p. 471. (Never described.)
1872 *Lygus redimitus* Uhler
U. S. Geol. Hayden Survey, Wyoming, Prelim. rept., p. 471. (Never described.)
1888 *Lygus rutilans* Horvath
Rev. d'ent. **7**: 181.
1900 *Lygus campestris* var. *fuscorubra* Strobl
Naturw. Verein Steiermark, Mitt. **36**: 188.
1906 *Lygus pratensis* var. *discrepans* Reuter
Mus. zool. St. Petersb., Ann. **10**: 39.

Reuter (1895, pp. 98–101) recognizes the following varieties:

Lygus pratensis punctatus Zetterstedt
L. pratensis rutilans Horvath
L. pratensis gemellatus Herrick-Schaeffer
L. pratensis pratensis Reuter
L. pratensis campestris Fallen
L. pratensis discrepans Reuter

The last-named was described by Reuter in 1906.

These varieties are based on a study of the forms occurring in the Old World. As yet the variation of the species has not been studied in this country.

NAME

In America and England the common name, tarnished plant-bug, is now universally employed. It was first used by Riley in 1870. Harris in 1841 called the insect the little lined plant-bug. Miss Ormerod, in England, in 1881 used the name "hop bug" for a variety known as *Lygus umbellatarum.* Florists sometimes refer to the insect as the chrysanthemum fly (Barker, 1895). In Germany it is known as the *grüne Wiesenwanze,* or green meadow-bug. The specific name *pratensis* is derived from the Latin, and means "found in meadows."

PLANTS INJURED BY THE TARNISHED PLANT-BUG

The tarnished plant-bug is almost omnivorous. It has been recorded as injuring about fifty plants of economic value. In the following list, abstracts are presented of the more important references to injury by this insect. All general statements of injury and all second-hand accounts have purposely been omitted.

Apple.— Walsh (1860), in Illinois, is the first to have recorded injury to apple-blossom buds by the tarnished plant-bug. Riley (1870 c) records severe injury to apple trees in Missouri. The adult bugs puncture the opening buds and destroy them. Popenoe (1874) records finding the insects in Kansas, abundant in and about apple blossoms which they were apparently injuring. Raymond (1880) states that in Iowa, in 1879, serious injury to apple buds was caused by this insect. Osborn records great injury to apples, especially Ben Davis, in the same year. Riley and Howard (1889) record a case in McPherson county, Kansas, where somewhat less than one fourth of the apple bloom was destroyed. Theobald (1905) states that during 1905 this insect seriously injured the unopened buds of apple in England. R. I. Smith (1906) records an instance in Georgia in which apple grafts were severely injured by tarnished plant-bugs. In Fig. 59 are shown two one-year-old apple trees from New York injured in this way. While the leaves were badly curled and the growth was severely checked, nevertheless the trees were able to outgrow the injury almost entirely by the end of the season. Hitchings (1908) states that in Maine the blossoms and the young fruit of apple were attacked, and that in many cases the latter was rendered knotty and unmarketable. This reminds one of injury by apple red-bugs and may have been caused by them, as Hitchings does not state that he actually saw the tarnished plant-bugs puncturing the fruit. Taylor (1908) describes and figures dimples in apples caused by the egg-laying punctures of the tarnished plant-bug. Collinge (1912) claims to have observed the same condition in England. Lind (1911) describes in detail injury to apple nursery and orchard trees by this insect in Denmark.

Pear.— Walsh (1860) is the first to have recorded injury to the buds of pear, which are punctured and killed by the tarnished plant-bug just as they are about to open. Riley (1870 c) records severe injury to pear trees in Missouri. Wier (1872) records a similar injury to pear buds both on bearing trees and on nursery stock. He alludes to this injury again in 1875, and describes an injury to the fruit which he attributes to the tarnished plant-bug but which was probably caused by the false tarnished plant-bug (*Lygus invitus*). The work of the latter insect has been described by Parrott and Hodgkiss (1913). Raymond (1880)

states that in Iowa during the previous year the tarnished plant-bug caused serious damage to pear buds. Osborn (1880) records it as especially destructive to pears, also in Iowa. Riley and Howard (1889) record an instance in McPherson county, Kansas, where one quarter to one third of the pear bloom was destroyed by the tarnished plant-bug. Johnson (1899 and 1900) records injury to the buds of pear nursery trees in Pennsylvania and Maryland. Theobald (1905) states that the insect is injurious to pear buds in England. Patch (1906) mentions injuries to leaf and flower buds of pear in Maine. Lind (1911) says that the insect causes considerable injury to pear leaf and flower buds in Denmark. R. I. Smith (1906) reports a case of severe injury to the buds of pear nursery stock in Georgia. We have observed a similar injury in a nursery near Rochester, New York.

Quince — Riley (1870 a) and Murtfeldt (1890 a) both refer to the tarnished plant-bug as being injurious to the buds and blossoms of quince, but give no specific instances.

Peach.— Lowe (1900) reports having observed the tarnished plant-bug puncturing peach fruits in June, causing them to wither and to exude gum. A discussion of injury to peach nursery stock caused by the tarnished plant-bug will be found on page 484.

Plum.— Wier (1872) reports serious injury to the buds of plum by this insect in Illinois. Raymond (1880) states that during 1877 it caused much damage to plum buds in Iowa. Johnson (1899 and 1900) records injury to the buds of plum nursery stock in Maryland and Pennsylvania. Theobald (1905) states that the insect has caused considerable injury to plum buds in England.

Cherry.— Raymond (1880) records serious injury in Iowa to cherry-blossom buds of the early-blooming varieties.

Apricot.— Murtfeldt (1890 a) mentions the fact that the tarnished plant-bug is especially destructive to blossoms and young shoots of apricot in Missouri.

Mulberry.— Lind (1911) states that the tarnished plant-bug often damages mulberry trees in Denmark.

Bramble fruits.— Forbes (1884 a) states that the blackberry and the raspberry are attacked by the tarnished plant-bug.

Currant and gooseberry.— Cook (1876) states that in Michigan he saw currants severely injured by the tarnished plant-bug, and Tullgren (1911) records it as injurious to this crop in Sweden. Murtfeldt (1890 b) records severe injury to gooseberries in Missouri. Lind (1911) states that currants and black currants (*Ribes nigra*) are often injured in Denmark by the tarnished plant-bug.

Strawberry.— Both the nymphs and the adults of the tarnished plant-bug are likely to attack the immature fruits of the strawberry, either

causing them to wither and die or making them one-sided and unmarketable. This trouble is known among strawberry-growers as buttoning. Forbes (1884 d) is the first to have described this injury. He records a case in which a loss of $5,000 to $10,000 was sustained by a grower at Cobden, Illinois. Cooley (1900) reports the tarnished plant-bug as very injurious to the strawberry in the Bitter Root Valley, Montana It is mentioned by Lind (1911) as being injurious to strawberries in Denmark.

Grape.— Bruner (1895) states that the tarnished plant-bug is sometimes injurious to grapes. Murtfeldt (1902) records the insect as injuring grape leaves in Missouri.

Potato.— The tarnished plant-bug is one of several insects that cause tipburn of potatoes. The injury is more noticeable in years of drought. Curtis (1840), in England, was the first to connect the tarnished plant-bug with this disease. Harris (1841) was the next to mention it in this connection, and in 1851 he discussed the question more fully. Cook (1876) observed serious injury to potatoes in Michigan. Patch (1906 and 1908) records injury to potatoes in Maine. Houghton (1909) states that during the previous season, in the northern part of Delaware, the tarnished plant-bug was very destructive to potatoes. Tullgren (1911) records injury to potatoes in Sweden by this insect. Britton (1914) states that it caused damage to this crop in Connecticut. Lind (1911) states that it is a serious enemy of potatoes in Denmark.

Beans.— The only reference that we have been able to find of injury to beans by the tarnished plant-bug is by Davis (1897). He states that considerable injury was done in Michigan during 1895 and 1896 to beans throughout the bean-growing sections of the State. The bugs punctured the pods, causing growth to stop at that point.

Beet.— Osborn and Gossard (1891) and Bruner (1891) state that the tarnished plant-bug is sometimes injurious to beets. The injury to beets in Europe is described by Rudow (1891).

On August 9, 1898, Professor Slingerland observed sugar-beet leaves curled or kinked, as shown in Fig. 65. Many eggs of the tarnished plant-bug were found inserted in the midrib and the larger veins of these leaves. In order to determine whether the injury to the leaves was caused by oviposition or by feeding, on the above date four cages were set up, each containing a beet plant. In each of two cages twelve males were placed, and in each of the other two cages twelve females. On the next day four more similar cages were arranged. One cage in which no bugs were placed was left as a check. In the cages containing the females many eggs were laid. On August 23 nearly all the leaves in all the cages, except the check, showed distinctly the kinking of the leaves due to injury to the midrib. This proves that the injury is due to feeding punctures, since it occurred in cages where males only were present.

Celery.— Troop (1892) mentions that the tarnished plant-bug is injurious to celery. Davis (1893) states that it is one of the worst insect pests of this crop in Michigan. The bugs puncture the tender stalks of the plants that are blanching, and produce large, brown, wilted spots which mar the appearance of the plants and lessen their market value. This injury is prevalent in New York and often causes celery-growers considerable loss.

Sea purslane.— Rudow (1891) describes malformations of this plant caused by the tarnished plant-bug.

Cabbage.— Riley (1870 a) and Thomas (1878) in this country, and Schoyen (1903), Tullgren (1911), and Lind (1911) in Europe, state that the tarnished plant-bug is sometimes injurious to cabbage.

Cauliflower.— Lind (1911) states that in Germany the tarnished plant-bug is injurious to cauliflower.

Turnips.— Tullgren (1911) in Sweden, and Lind (1911) in Denmark, state that turnips are sometimes attacked by this insect.

Salsify.— Webster (1890 a) states that nymphs and adults of the tarnished plant-bug were found feeding in abundance on salsify in Ohio.

Cucumbers.— Riley (1870 c) records a case of severe injury to late-planted cucumbers at Chicago, Illinois.

Tobacco.— Lintner (1890) has recorded an instance in which the tarnished plant-bug was found feeding on the tobacco plant. Britton (1905 and 1907) is of the opinion that this insect causes injury to tobacco in Connecticut.

Hydrangea.— Lind (1911) states that hydrangeas are sometimes injured by the tarnished plant-bug in Denmark.

English laurel (*Prunus laurocerasus*).— Lind (1911) states that this plant suffers somewhat in Denmark from the attacks of the tarnished plant-bug, which punctures the leaf buds, causing them to wither or causing the leaves to have a deformed and crumpled appearance.

Chrysanthemum.— The tarnished plant-bug attacks the unopened buds of the chrysanthemum, causing an injury known as blind growths, or blind buds. While more destructive in the open, the insects sometimes become troublesome in greenhouses. Webster (1888) reports such a case at Purdue, Indiana. Lind (1911) states that the tarnished plant-bug is very destructive to chrysanthemums grown in the open, and sometimes in greenhouses, in Denmark. Witte (1893) states that in Germany chrysanthemums are injured by this insect. Certain late varieties, such as Fair Maid of Guernsey, Mount Mascal, and Stanstead White, are especially susceptible, while the Fanny Boucharlat is immune. Brief records of injury have been made by Jack (1890), Murtfeldt (1890 b), Sorauer (1896), Barker (1895), Felt (1898), Reh (1902), and Theobald (1903).

Dahlia.— The tarnished plant-bug is a serious enemy of dahlias. The bugs puncture the tips and the unopened buds (Fig. 63) and thus stunt the plants, causing them to stool out close to the ground. The injury also prevents the opening of the blossom buds or produces imperfect flowers. Many eggs are often deposited in the buds and the tender tips. Harris (1841) was the first to call attention to this injury to dahlias. It has also been mentioned by Strachan (1893), Britton (1905 and 1914), Patch (1906), and Arnold (1912) in this country, and by Sorauer (1896) and Tullgren (1911) in Europe. Injured and uninjured dahlia plants are shown in Figs. 61 and 62. Lind (1911) discusses at length injury to dahlias by the tarnished plant-bug in Denmark.

Peony.— Pugsley (1880) reports a case in 1877, in Kansas, when over one thousand peony buds were destroyed by the tarnished plant-bug.

Carnation.— The only reference to injury to this plant that we have been able to find is a mere statement by Davis (1896).

Aster.—In many parts of the country the tarnished plant-bug is the most serious insect pest with which the aster-grower has to contend. The bugs puncture the terminal buds and stunt the plants. They attack the blossom buds also, which either do not open at all or produce imperfect flowers. A stunted plant is shown in Fig. 60.

Harris (1841) was the first to note injury to asters by the tarnished plant-bug. Webster and Mally (1897) in Ohio, Cooley (1900) in Montana, Patch (1906) in Maine, and Felt (1904) in New York, mention this insect as producing serious injury to asters. Arnold (1913) has given a good account of the injury, and describes experiments by Faulwetter proving that the tarnished plant-bug is the cause. He states that certain early varieties, such as Queen of the Market, escape serious injury because they make most of their growth before the bugs become abundant; later varieties are attacked in late July and August. Arnold calls attention also to the fact that asters grown in the shade of old apple trees were unaffected, while those grown in the open were badly stunted. We also have noticed the beneficial effect of shade in preventing injury. In large aster fields grown for seed at Baldwinsville, New York, two or three rows of corn are used to separate the varieties. The asters in the rows next to the corn and partially shaded by it show less injury than do the others.

A good account of injury to asters caused by the tarnished plant-bug, with excellent illustrations of affected plants, is given by Arnold (1912). He states that the bugs cause a sort of " pinching back," which produces a dwarfed, bunched, thickened appearance as distinguished from the symmetrical dwarfing caused by lack of moisture.

Other Compositae.— Arnold (1912) states that he has noted that the following composite plants are often affected: *Brachycome; Calendula;*

Centaurea Cyanus and *C. moschata; Tagetes,* especially *T. erecta;* and of the everlastings, particularly *Acroclinium* and *Helichrysum.* Harris in 1841 had already called attention to injury to marigold.

Antirrhinum and *salvia.*— Arnold (1912) mentions injury to these plants.

Balsam.— Harris (1841) makes the only first-hand reference to injury to balsam, although his statement has been repeated by many writers.

Urtica.— Kaltenbach (1874) lists the tarnished plant-bug as an enemy of *Urtica dioica.*

Pastinaca.— Kaltenbach (1874) mentions the insect as injurious to *Pastinaca sativa.*

Fuchsia.— Karsch (1889) mentions this plant as being injured by the tarnished plant-bug.

Dicentra.— Pugsley (1880) states that in Kansas in 1877 the tarnished plant-bug seriously injured this plant.

Poppy.— Theobald (1905) records a case in England in which beds of poppies were ruined by the tarnished plant-bug in July and August.

Sweet pea.— Weed (1901) describes a case of severe injury to sweet peas in New Hampshire. The bugs punctured the flower stalk, usually just below the bud, causing it to wither and die.

Lilac.— Pugsley (1880) mentions injury to lilacs by the tarnished plant-bug.

Dwarf mountain June berry.— Pugsley (1880) records the destruction of the blossom buds of this shrub.

Corn.— Cook (1876) states that in Cass county, Michigan, corn was injured to a considerable extent.

Wheat.— Cook (1876) states that in the same locality about ten per cent of the wheat crop was destroyed. Webster (1886) observed that in Indiana tarnished plant-bugs were abundant on wheat and were extracting the milk from the immature kernels. The insects were apparently more destructive to the spring than to the fall varieties. Schöyen (1911) records the tarnished plant-bug as injurious to wheat in Norway.

Oats and barley.— Schöyen (1911) found the insect feeding on these grains.

Timothy.— Schöyen (1911) records the insect as feeding on timothy grass.

Hops.— Ormerod (1881) considers the tarnished plant-bug as an enemy of hops in England.

THE TARNISHED PLANT-BUG AND THE TRANSMISSION OF FIRE BLIGHT

Indirectly the tarnished plant-bug causes great injury to apple, pear, and quince, especially nursery stock, by carrying the fire-blight bacteria

to healthy trees. Forbes (1884 a) was the first to suggest that this insect is instrumental in the dissemination of fire blight. He says: "There is considerable reason to suppose that these insects are often active agents in conveying the virus of the blight of the pear and apple from tree to tree by inoculation with the infected sap." Stewart (1913 c) proved experimentally that the tarnished plant-bug is capable of transmitting the disease.

LIFE HISTORY

Hibernation

In New York, as a rule, the tarnished plant-bug hibernates in the adult stage. Forbes (1884 d) states that the older nymphs also survive the winter, under the leaves of mullein plants. Wier and others state that only the females hibernate, the males dying in the fall after copulation, but this does not agree with our observations; we have found males and females about equally abundant in hibernation. We are told by S. C. Bishop, who has studied the female reproductive organs in the fall, that no developed eggs were found in females collected at Ithaca, New York, in October. Wier states that the insects hibernate also in the egg stage.

It is not easy to find the hibernating adults. On November 14, 1911, we spent several hours in searching for them in the vicinity of a block of peach nursery trees at Honeoye Falls, New York. Only two were found, both males — one was under a stone in the bottom of a stone pile at the edge of a piece of woods, and the other was sifted from leaves collected in the woods. The insects hibernate also among the fallen leaves in nursery blocks. In such a situation a male and a female were sifted from peach leaves on November 28, 1913, and on the following day a female was sifted from apple leaves and two females and another male were sifted from peach leaves. Students at Ithaca sifting leaf mold for insects during the winter occasionally find specimens of the tarnished plant-bug. On December 22, 1913, H. H. Knight collected a male and four females in trash under maples on the flats at Ithaca. On February 1, 1914, H. Morrison found a female under the bark of a dead tree at Ithaca.

Some of the bugs do not go into hibernation until the advent of decidedly cold weather. We have swept them from the dead blossoms of asters and goldenrod as late as November 6 at Ithaca.

First appearance in spring

The over-wintering adults become active with the first warm days of spring. Our earliest record is March 20, when a single specimen was found resting on low grass in a meadow near Penn Yan, New York.

Early spring food-plants

The adults attack the opening buds of apple, pear, quince, and plum, but do not breed to any great extent on these plants. In the early part of the season they are found most abundantly in grassy fields and on low weeds, and apparently they breed in such places. Chittenden and Marsh (1910) record finding adults common on mullein as early as April 19 at Washington, D. C. Little definite information has been recorded concerning the early spring food-plants of the insect.

Oviposition

On August 10, 1898, Professor Slingerland observed the egg-laying of the tarnished plant-bug, on the midrib of a beet leaf in a cage in the Insectary. His notes are as follows: "I saw one egg laid, the time occupied in the oviposition being nearly a minute. The ovipositor was sunk into the tissue of the midrib of the leaf nearly to the full extent." This observation is at variance with the statement of Haseman (1913): "The ovipositor of the tarnished plant-bug does not seem to be sufficiently strong to enable it to drill into tissues of plants."

On peach the eggs are usually inserted into either the side of the tender tip (Fig. 64), the leaf petiole, or the midrib of the leaf. According to Professor Slingerland's observations the eggs are inserted into the blossom buds of dahlias, sometimes to the number of eight. Chittenden and Marsh (1910) record finding the egg on kale, slightly inserted in the upper side of the leaf. They also found eggs in the seed stalks, stems, and leaves of volunteer turnip, *Brassica campestris*, scattered about singly and in irregular rows or groups, sometimes three being placed close together. In mullein the eggs are inserted in the petiole and in the midrib. Haseman (1913) states that in the latter part of the season, in Missouri, the eggs are deposited in the flower heads of various species of composite plants such as daisies, asters, and mare's-tail (*Erigeron canadensis*). We have often found the eggs in the flower heads of the daisy fleabane, *Erigeron ramosus*, in October; some of them are inserted about one fifth of their length into the receptacle, while others adhere to the side of the ovary of a floret. As a rule, when the eggs are deposited in stems, petioles, or similar structures they are inserted to their full length and the end is flush with the surface (Fig. 67), but when placed in flower buds they are tucked in between the flower parts. Taylor (1909) found the eggs deposited in young apples.

According to the observations of Professor Slingerland the egg stage is about ten days.

The egg

The egg is .95 to 1 millimeter in length by .25 millimeter in width, flask-shaped, obliquely truncate, and at the anterior end slightly curved and compressed toward the apex (Fig 66)

Nymphal stages

On hatching, the young tarnished plant-bug is a small, greenish creature, less than $\frac{1}{25}$ inch in length. It runs about actively and soon begins feeding on the juices of the plant, which it extracts by means of its beak. In the course of development the insect molts five times, acquiring wings at the fifth molt.

Stage I.— Length, .96 millimeter. General color, yellowish green, the yellow being more pronounced on the head. Body sparsely clothed with short black hairs. Eyes gray. Antennæ dusky; second segment with a paler band in the middle. Position of dorsal abdominal gland indicated by a dark spot between the third and fourth segments; a yellowish spot in front of the opening of the gland. Coxæ and trochanters greenish, remainder of legs suffused with dusky, darker on the tarsi. Head yellowish beneath. Beak extending to about the middle of the abdomen, greenish, tip dusky. (Fig. 50.)

Stage II.— Length, 1.36 millimeter. Body relatively narrower than in the first stage. A pair of small dark spots on the first and second thoracic segments, usually indistinct. Antennæ brownish, yellow at the articulation of the segments; second segment with a pale median band. Legs greenish yellow; tarsi dusky; femora with two indistinct dusky bands above, toward the tip; tibiæ with a blackish spot at the base above. (Fig. 51.)

Stage III.— Length, 2.05 millimeters. General color, yellowish green; green or greenish yellow below; tip of abdomen dusky. Wing pads begin to show, and extend onto the second abdominal segment. Antennæ similar to preceding stage. The two pairs of black spots on the thorax conspicuous, the anterior pair sometimes indistinct; a small black spot on the underside of the posterior angle of the prothorax is also present. Faint suggestions of darker markings on thorax appear in this stage. Abdominal gland indicated by a black spot. Legs as in preceding stage except that the tarsi are lighter toward the base. Beak extends to base of abdomen, yellowish green, tip dusky. (Fig. 52.)

Stage IV.— Length, 3.1 millimeters. General color, greenish, with dusky or reddish brown markings which are less distinct than in the next stage. Sometimes the whole insect has a reddish tinge. Wing pads extend to the third abdominal segment. (Fig. 53.)

Stage V.—Length, 4.02 millimeters. Head pale green; margin inside the eyes and hind margin brownish; there are also three brownish lines radiating from a point midway between the eyes. In some specimens these markings are very indistinct. Eyes elongate oval, gray. Ground color of thorax and wing pads yellowish, irregularly marked with lines and spots of brownish. Some specimens are very pale, while in others the darker color covers nearly the whole surface. The two pairs of black spots are very conspicuous. A narrow yellowish median line is always present. Hind border of the wing pads usually darker. The ground color of the abdomen is yellowish or greenish yellow; each segment is marked with two transverse bands of reddish brown, one at the base and the other at the middle of the segment. These bands do not reach to the lateral margins of the abdomen. In some specimens the abdomen is nearly a uniform green with a yellowish margin, while in others the markings are very distinct giving the abdomen a decidedly reddish appearance. Extreme tip of the abdomen usually darker. Dorsal abdominal gland indicated by a conspicuous black spot. Under surface of the insect yellow or greenish yellow. Thorax irregularly spotted with reddish brown, a round black spot on the posterior angle of the prothorax. Posterior half of the abdomen reddish; lateral margin dark. On each side there is a row of greenish or yellowish spots, one on each segment. Antennæ reddish brown, first segment darkest, second segment with a pale median band, and third segment narrowly pale at base. Legs very variable in coloration. In the lighter specimens yellowish suffused with reddish brown; femora with two reddish bands near the tip; tibiæ with a black spot at base above, reddish at tip; tarsi black at base and tip, paler in the middle. In the darker specimens the legs are reddish; femora tipped with yellowish and with a band of yellow toward the tip on the first and second pairs of legs; posterior femora with two bands; tibiæ narrowly yellow at base, followed by a broad reddish band; tip reddish. All gradations in coloration occur. Wing pads extend onto the fifth abdominal segment. (Fig. 54.)

Adult.—Length, $\frac{1}{5}$ to $\frac{1}{4}$ inch. Very variable in coloration. General color brownish, mottled with various shades of yellowish and reddish brown. The head yellowish brown, usually marked with three longitudinal lines, brownish, black, or reddish in color and very variable in distinctness. The prothorax bronzy brown, usually with four more or less distinct blackish spots in a row, one third the distance from the front margin, very variable in size, shape, position, and distinctness, and sometimes so arranged as to give the prothorax the appearance of having four longitudinal dark stripes. The posterior angles of the prothorax marked with a dark brown, black, or red spot. Scutellum varying from brown

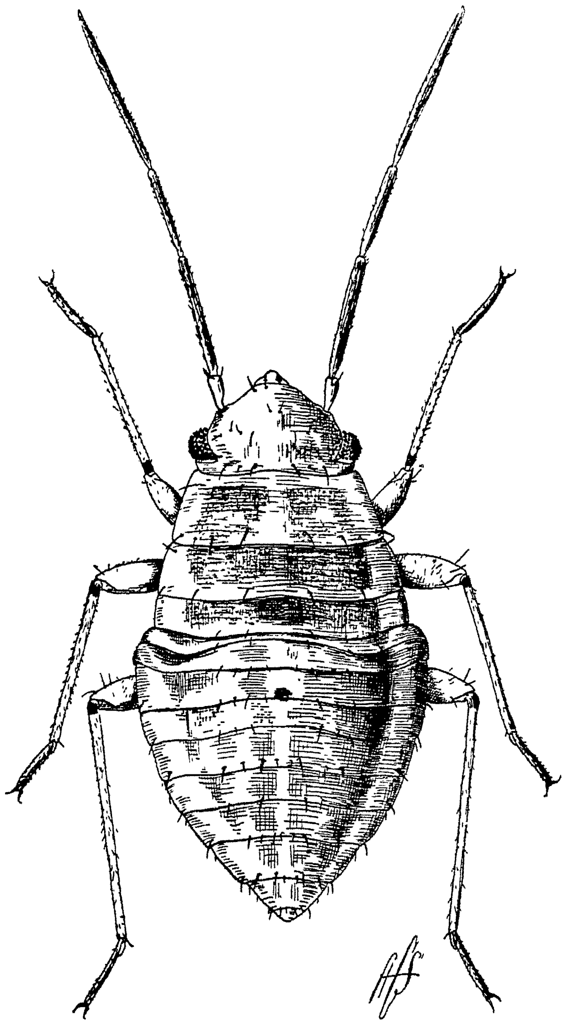

FIG. 50.— *Tarnished plant-bug, first-stage nymph. Length, .96 millimeter*

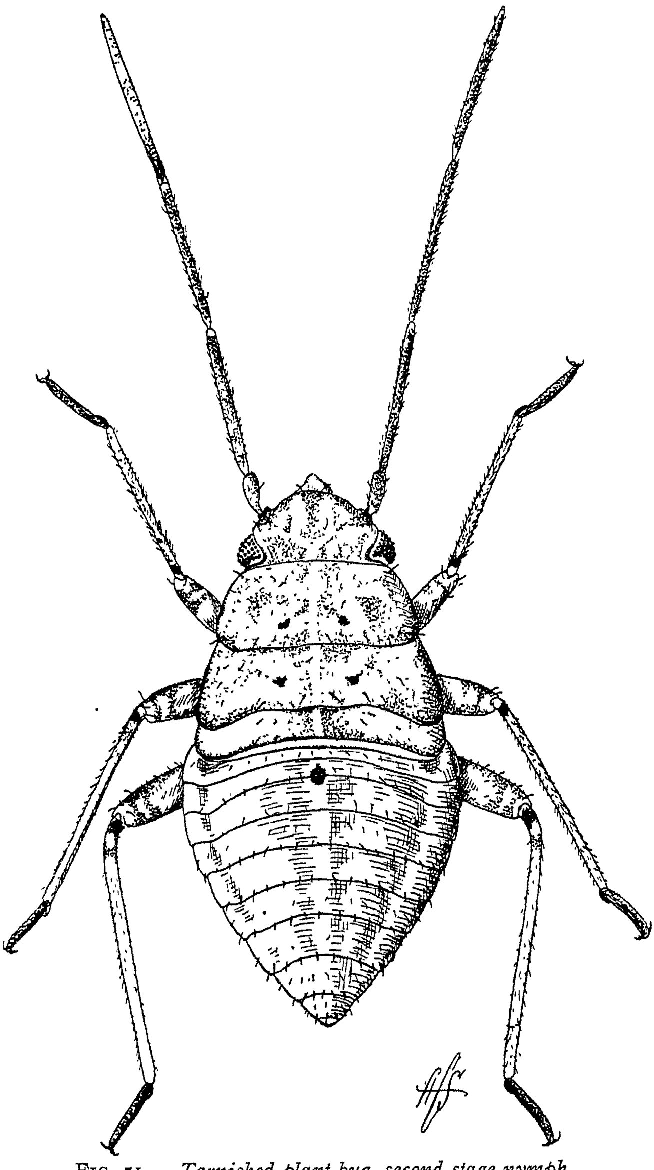

FIG. 51.— *Tarnished plant-bug, second-stage nymph. Length, 1.36 millimeter*

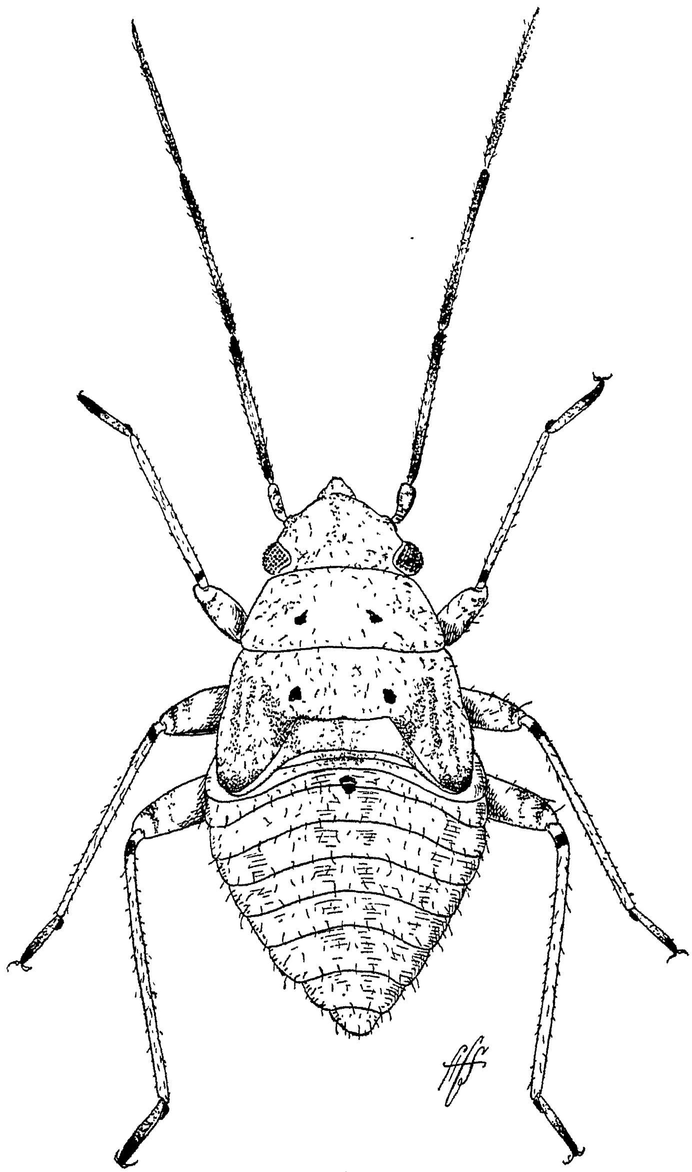

FIG. 52.— *Tarnished plant-bug, third-stage nymph. Length, 2.05 millimeters*

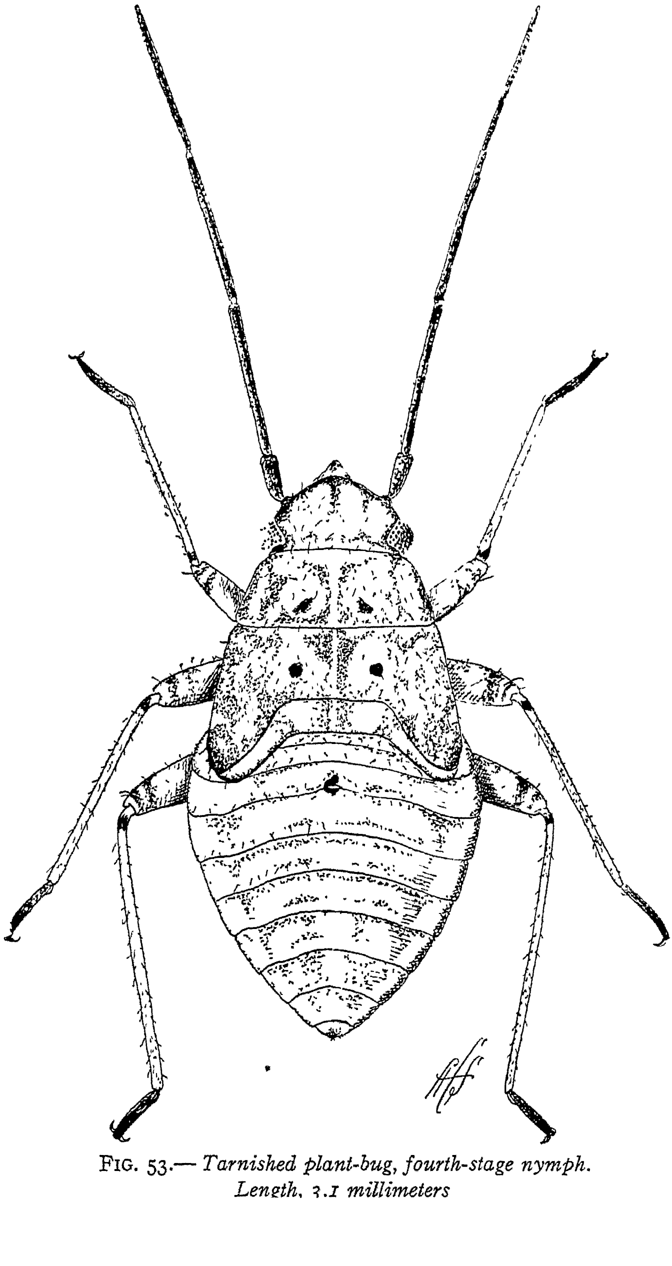

FIG. 53.— *Tarnished plant-bug, fourth-stage nymph. Length, 3.1 millimeters*

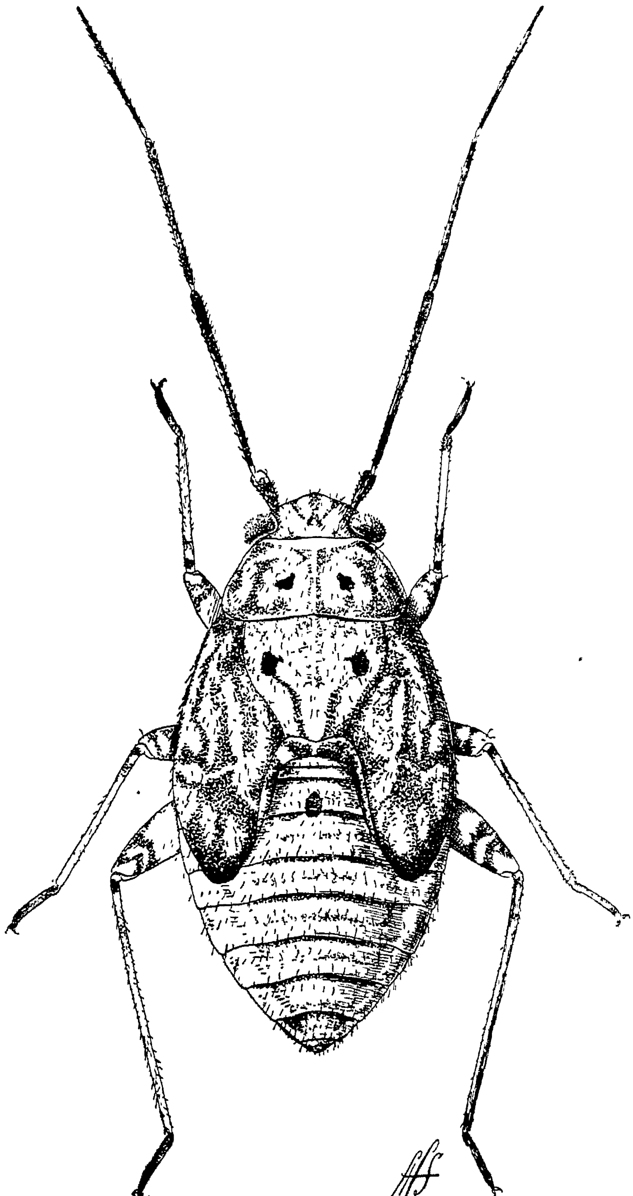

FIG. 54.— *Tarnished plant-bug, fifth-stage nymph. Length, 4.02 millimeters*

to black or reddish, and usually marked with a heart-shaped or Y-shaped spot on the posterior half. This spot is sometimes broken up into three smaller spots. Wings bronzy brown, mottled with yellowish brown and reddish. Cuneus usually lighter, with the tip black or dark reddish. Antennæ dark brown; the first segment and the second segment, except the tip, usually lighter. Legs light yellowish brown to dark reddish; posterior femora with two reddish rings near the tip. Sometimes the fore and the middle femora have similar but less distinct bands. Tibiæ with a dark band near the base and at the tip. Tarsi dusky. Under surface of the insect dark in the center, with a lighter stripe on each side; there is a marginal band of brownish in which there is a submarginal row of yellowish spots, one to each segment. In some specimens the bright band covers nearly the entire surface, while in others the black is predominant and replaces the brown of the marginal band. As a rule the males are somewhat darker and smaller than the females. (Fig. 68.)

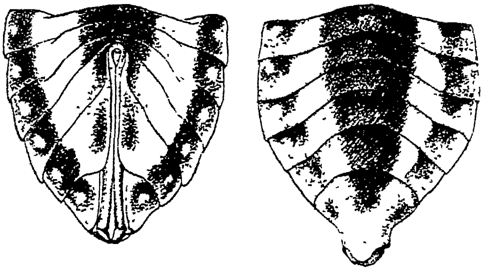

FIG. 55.— *Tarnished plant-bug, ventral view of abdomen of female and of male*

The ovipositor when at rest lies nearly concealed in a groove on the underside of the abdomen (Fig. 55). It consists of two pairs of parallel blades, an inner and an outer pair. In Fig. 56 is shown a side view of one of the outer blades. Each of the outer blades is provided with a chitinous, recurved, basal rod, which runs up into the abdomen and serves for muscle attachments. The blade is spear-shaped, enlarged toward the tip, and then tapering to a sharp point. The tip is armed with strongly chitinized, recurved teeth. The inner blades are similar in shape; the tip, however, is not provided with chitinous teeth, but is scalloped. Each blade is strengthened by a more strongly chitinized part which extends longitudinally along its median line. The inner blades are grooved into the concave inner surface of the outer blades.

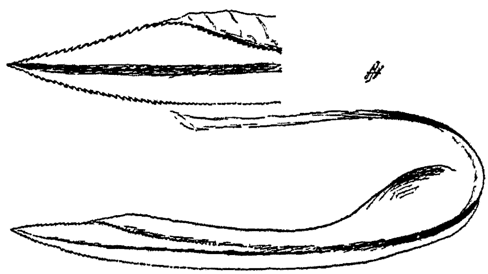

FIG. 56.— *Tarnished plant-bug, lateral view of ovipositor; upper figure, the tip enlarged*

Haseman (1913) finds that in Missouri the life cycle is completed in

twenty-five to thirty days in September and October, and he is of the opinion that in the summer only twenty to twenty-five days are required. This would give four or five generations of this insect in each season.

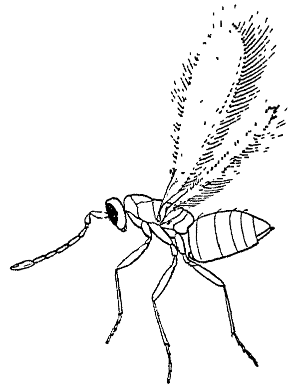

FIG. 57.—*Anagrus ovijentatus, adult*

Natural enemies

The tarnished plant-bug is singularly free from the attacks of natural enemies. The eggs are destroyed to a slight extent by a minute Mymarid parasite, *Anagrus ovijentatus* Crosby and Leonard (Can. Ent. **46:** 181–182). On October 3, 1913, while examining flower heads of the daisy fleabane, *Erigeron ramosus*, we found one egg and two eggshells of the tarnished plant-bug, with the tip of the egg slightly inserted in the receptacle of the flower head. The flower head was placed in a vial and in a few days the egg took on an abnormal blackish color. On October 7 a specimen of the parasite emerged. From other flower heads placed in a breeding cage two other parasites of the same species were obtained on October 21 and 27, respectively. The technical description of this parasite is as follows:

Anagrus ovijentatus Crosby and Leonard. (Fig. 57.) Female. Length .64 millimeter, abdomen .36 millimeter. General color black; eyes dark red; antennæ blackish, except pedicel below and scape at tip, which are dull yellowish. Legs dull yellowish; coxæ dusky; femora broadly banded with dusky; middle and hind tibiæ dusky, except tip and base; last tarsal segments dusky. Abdomen black, very slightly tinged with yellowish at the tip.

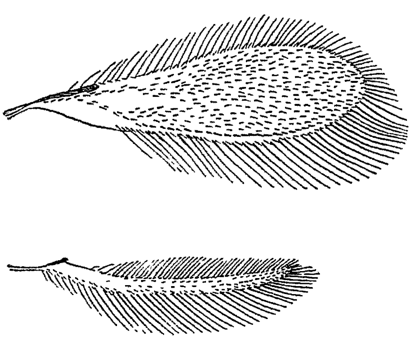

FIG. 58.— *Fore and hind wings of Anagrus ovijentatus*

The relative length of the antennal segments is indicated by the following ratio: scape 4, pedicel 3, first funicle 1, second 2, third, fourth, fifth, sixth, 3, club 5.

The ciliation of the wing is shown in Fig. 58.

Garman (1890) states that he has observed a fungus, *Empusa* sp., attacking the tarnished plant-bug in Kentucky, and he suggests that this is in part the reason why damp weather tends to decrease the number of the insects.

tch (1907) records evidence showing that in Maine the hibernating ts are destroyed by ground-beetles and rove-beetles.

rds.— In spite of the abundance of the tarnished plant-bug on all s of weeds and other plants throughout the growing season, only w birds are known to feed on it and these to only a slight extent. bes (1884 d) says:

the food of three hundred and fifteen robins, cat-birds, and other thrushes, taken l seasons of the year, and carefully studied by me, only two birds, both robins, eaten this species, and these in merely trivial amount. One hundred and eight birds had not taken it at all, although from their food-habits and haunts, one would ose the insect especially exposed to their notice. Fifty specimens of the common -throated bunting of Central Illinois, shot at the time when this plant bug swarms abundantly upon vegetation everywhere, had eaten only a single specimen. e instances will serve to illustrate the fact that for some unexplained reason this dant species is scarcely at all endangered by the presence of insectivorous birds.

. L. McAttee, of the United States Biological Survey, has informed us the records of the Survey show that the tarnished plant-bug has been d in the stomach of the chimney swift, the nighthawk, and the bob-te, only.

INJURY TO PEACH NURSERY STOCK

each nursery trees injured by the tarnished plant-bug present a rfed and bushy appearance, due to the killing of the terminal buds of h the laterals and the main shoot by the feeding punctures of the lts in late June and early July (Fig. 72). Observations of the last years show that only a very few tarnished plant-bugs are to be found he peach blocks before the latter part of June. In 1912, and again 1913, about June 23 they suddenly increased in numbers and within eek became extremely abundant. The injury to the buds followed ely after the increase in the number of the insects.

he bugs are usually seen resting on the foliage; they are very active l shy, taking flight at the slightest alarm. We have often observed m feeding on the terminal buds and the tips of the tender shoots, which y puncture with the fine, needle-like bristles of the beak.[2] At this time trees are about thirty inches in height and growing rapidly; the tips the branches are very tender and delicate, and terminate in several all, unopened leaves. When the tip has been punctured the leaves t, turn brown, and die (Fig. 69); the bud also is killed (Fig. 70) d further growth of the branch is prevented. Not only the terminal d of the leader, but also those of all the laterals, are injured in a similar anner. By July 10 practically all the buds were stung.

This injury to peach nursery trees has been ascribed to other causes. hnson (1898 and 1900), Phillips (1906), and Quaintance (1912) attributed

The tarnished plant-bug on rare occasions becomes bloodthirsty. One of the authors has twice been en on the neck by one of these bugs. The sensation is similar to a mosquito bite, but the subse-nt irritation is not so great.

it to a mite. Banks (1912) described the mite observed by Quaintance as *Tarsonemus waitei*.

A similar injury was described by Smith in 1900. He believed a species of thrips to be responsible. In a letter quoted by Smith, William B. Alwood, of the Virginia Agricultural Experiment Station, states that he has been familiar with this injury since 1891 and is of the opinion that the culprit is *Euthrips tritici*. We have received from two nurseries in Alabama peach trees showing characteristic stop-back injury. In one instance the nurseryman stated that this trouble had been attributed to various causes, such as poor soil conditions, lack of drainage, or root rot.

The first to attribute stop-back injury of peach nursery stock to the tarnished plant-bug was Slingerland (1895 a). He states that in the previous year he had investigated an injury to the terminals of peach nursery stock which he considered to be caused by the tarnished plant-bug. Webster and Mally (1899) reached the same conclusion from observations made in Ohio. They noted that the extent of the injury was correlated with the abundance of the tarnished plant-bug in the nursery blocks.

Back and Price (1912) proved experimentally that the injury is caused by the tarnished plant-bug. They placed cheesecloth cages over a number of trees growing in the nursery. In some of these cages tarnished plant-bugs were placed; other cages were left as checks. In all the cages where the bugs were introduced the characteristic injury soon became apparent. In the checks the plants remained healthy.

Haseman (1913), as a result of observations in Missouri covering two years, concludes that the tarnished plant-bug is responsible for the injury. Many years earlier, in 1895, Professor Slingerland produced the injury experimentally by caging the bugs on peach tips. His notes are as follows:

June 29, 1895. Placed a bag over two peach shoots and put six bugs just swept from grass in the bag.

July 9. Noticed that one of the tips in the bag was injured and one leaf had turned brown and died. There was one live bug still in bag. This seems conclusive evidence that the bugs are the cause of the injury.

In June, 1912, L. I. Snodgrass conducted similar experiments in order to determine whether the bugs were responsible for the injury, and also the amount of injury that could be caused by males, females, and nymphs, respectively. His experiments were as follows:

Experiments set up June 27	*Result July 3*
Bag I, 3 needle punctures	No injury
Bag II, 3 needle punctures	No injury
Bag III, 5 females	Severe injury
Bag IV, 5 males	Slight injury

Experiments set up June 27	*Result July 3*
Bag V, 5 females	Severe injury
Bag VI, 5 males	No injury
Bag VII, 5 nymphs	Severe injury
Bag VIII, check	No injury

The results of these experiments indicate that peach stop-back injury is produced by the tarnished plant-bug. The fact that injury was produced by nymphs would indicate that it was caused by feeding punctures. The fact that injury was not produced by needle punctures would suggest that, in feeding, the insect injects some substance poisonous to the plant tissue. The fact that the injury was greater in the bags where females alone were present than where males alone were present would indicate that the females may increase the injury by their egg-laying punctures.

Amount of injury

The losses occasioned by tarnished plant-bug injury to peach nursery stock are very great. The trees are stunted and bushy and do not have a strong leader, and must therefore be sold as second- or third-class stock. While these trees do not have the proper form, nevertheless they are perfectly thrifty and in many cases are as good for planting as those having a large, fully developed leader, if not better. Furthermore, the root system of these trees is sometimes better developed than when the growth has all gone into the tops. As an indication of the extent of the injury it may be noted that many nurserymen's catalogues are illustrated with photographs of peach trees which show to a slight extent the characteristic injury.

Several estimates have been made of the losses occasioned by the tarnished plant-bug to peach nursery stock in various parts of the country. These estimates, however, give little real information as to the actual prevalence of the injury. In some cases the percentage of trees injured is given, without any statement as to whether or not they outgrew the injury. No information is given as to their condition at digging time; whether they were a total loss or could be sold as second-class stock is not indicated. In other cases a statement is made that a certain number of trees are injured, but the whole number of trees grown in the locality is not given. Again we are told that a loss of a certain number of dollars is sustained. Whether this is important or not would depend on the amount of business transacted by the firm. In view of these facts the following statement, kindly furnished by one of the largest nursery firms in New York State, will be found of interest:

In the fall of 1912 a block of 188,000 peach trees was budded. They

FIG. 59.— *Apple nursery trees injured by the tarnished plant-bug*

FIG. 60.— *Aster plant badly dwarfed by the tarnished plant-bug. Three branches have escaped injury and are making normal growth. (Courtesy of George Arnold)*

FIG. 61.— *Dahlia plant injured by the tarnished plant-bug*

FIG. 62.— *An uninjured dahlia plant*

FIG. 63.— *Dahlia shoot injured by the tarnished plant-bug*

Fig. 64.— *Injured peach tip showing egg of a tarnished plant-bug in position, enlarged*

Fig. 66.— *Section of dahlia stem showing eggs of tarnished plant-bug in position, enlarged*

Fig. 67.— *Surface of a beet leaf showing the tips of three eggs, enlarged*

Fig. 65.— *Beet leaf kinked by the tarnished plant-bug*

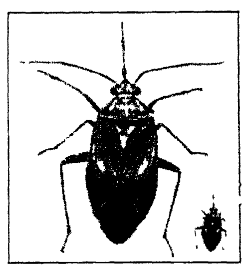

Fig. 68.— *Tarnished plant-bug, enlarged and natural size*

FIG. 69.— *Peach tips showing the typical injury by the tarnished plant-bug*

FIG. 70.— *An injured peach tip, enlarged*

FIG. 71.— *Applying lime and sulfur dust with a milk-pail pepperbox*

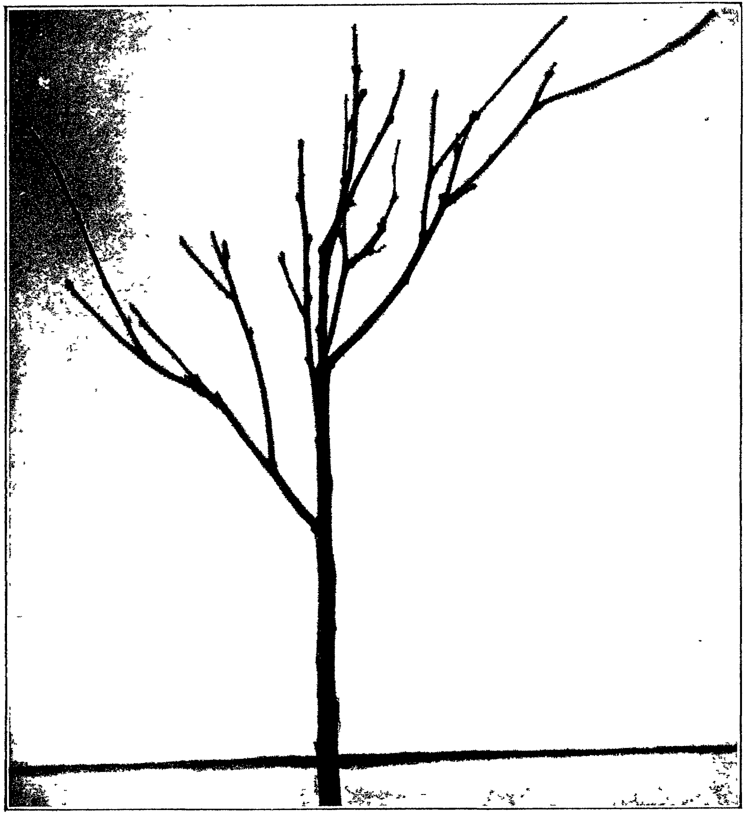

FIG. 72.— *A typical case of peach stop-back caused by the tarnished plant-bug*

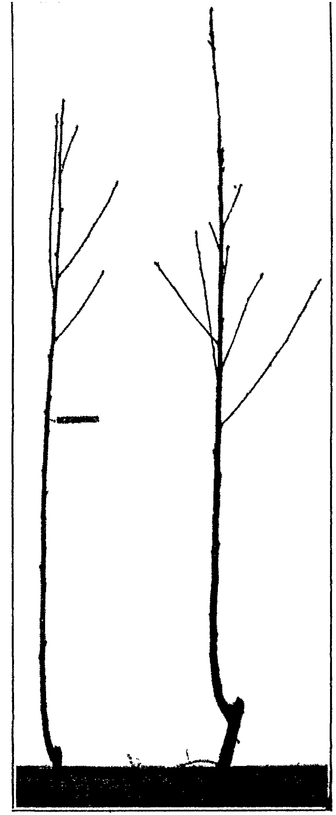

FIG. 73.— *Uninjured trees*

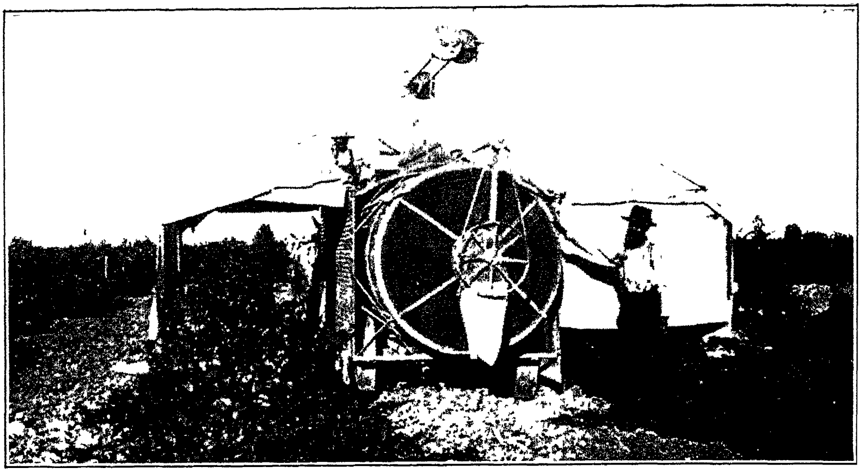

FIG. 74.— *A suction machine for collecting grape leaf-hoppers, in use in California*

FIG. 75.— *Applying dust to peach nursery stock with a Brownie duster*

FIG. 76.— *Sticky shields used in attempt to capture tarnished pl bugs in the nursery*

were dug in the fall of 1913 and were graded as follows: No. 1, 25,000; No. 1, shorts, 8,000; No. 2, 17,000; No. 3, 18,000; a total of 68,000 trees, which is about 36 per cent of the budding. At the present market value these trees are worth $2865. It is a reasonable supposition that under ordinary conditions 80 per cent of the buds would have produced salable trees divided as follows: No. 1, 40 per cent, 75,200 trees; No. 2, 20 per cent, 37,600 trees; No. 3, 20 per cent, 37,600 trees. In fact, a good block might do even better. But even on this basis and at present values the trees would be worth $6900; that is, in this case there was an estimated loss of approximately $4000 on a block of 188,000 budded trees.

In this case every tree was badly stung by the tarnished plant-bug, but it is hardly fair to attribute all the loss to this cause. The prolonged drought of 1913 had considerable to do with it, since under more favorable conditions many of the trees would have been able in a large measure to outgrow the injury; and, even if they had not made first grade, they would have made a larger proportion of seconds and thirds. In 1913 only 36 per cent of the trees budded were salable; in a favorable year 80 per cent of them would have made at least third grade. It is difficult to determine what proportion of this loss is to be attributed to the tarnished plant-bug and what proportion to the drought; for, as a rule, the bugs are less abundant in wet seasons, when the trees are better able to outgrow the injury, and in dry seasons the bugs are more abundant while at the same time the trees are less able to recover.

MEANS OF CONTROL

The control of the tarnished plant-bug is still an unsolved problem. Most of the remedies suggested are either inadequate to meet the demands of practical growers, unsuited to the conditions under which the crop is grown, or impracticable in other ways. Most of the recommendations have been made without any experimental evidence as to their value and often without any apparent knowledge of the difficulty of the problem. In fact, with the single exception of Forbes' (1884 d) experiments with kerosene emulsion and pyrethrum, the only actual tests of the effect of insecticides on the bugs, of which we have any record, are those of two practical farmers, Earle (in Forbes, 1885) and Ayers (in Riley, 1870 c).

Recommendations made in the past for the control of the tarnished plant-bug may be grouped under the following heads: contact insecticides, deterrents, mechanical methods, and cultural practices.

Contact insecticides

Contact insecticides have been repeatedly recommended for killing the tarnished plant-bug, apparently without realization of the difficulty

of hitting these active and wary insects or of killing them even when they are hit.

Kerosene emulsion.— This insecticide, owing to its successful use against other sucking insects, has been widely recommended for destroying the tarnished plant-bug. Forbes (1884, a and d) was the first to recommend kerosene emulsion. He describes a number of experiments in which the emulsion was applied to the insects in captivity. He used an emulsion made with sour milk at two strengths, one containing $2\frac{1}{2}$ per cent and the other 5 per cent of oil. Even under laboratory conditions, where it was possible to thoroughly wet the insects and where they were confined under a bell jar or in cages after the application, very indifferent results were obtained.

Many later writers have perfunctorily recommended kerosene emulsion for the control of the tarnished plant-bug in spite of the fact that in most cases the greater part of the injury is inflicted by the adult bugs, which are both hard to hit and difficult to kill even when struck with the spray. Two or three writers state that the results of the application were successful, but the basis for this conclusion is not apparent from their accounts.

A mechanical mixture of kerosene and water has also been recommended by Johnson (1899 and 1900) and by Sanderson (1902). Witte (1893) recommends the use of petroleum and water, 1–500. Gossard (1908) advises the use of kerosene emulsion made with pyrethro-fish-oil soap.

Pyrethrum.— As a result of laboratory experiments with pyrethrum, in which the bugs were confined under a bell jar and in bottles, Forbes (1884 d) strongly recommended its use for the control of the tarnished plant-bug; but field experiments by Earle (in Forbes, 1885) showed that it was of little practical value when used in strawberry fields. In spite of this the use of pyrethrum has been a stock recommendation of later writers.

Pyrethrum is unsatisfactory for the same reasons as is kerosene emulsion, and furthermore it is too expensive for use on a large scale.

Soaps.— Ever since Harris, in 1841, suggested the use of soapsuds for the control of the tarnished plant-bug, it has been the fashion for writers to advise the use of soap solutions. Whale-oil soap has been most widely recommended. Riley, in 1870, advised the use of cresylic soap. E. J. Ayers, of Villa Ridge, Missouri, tried this soap and the report of his experience is of interest:

I first tried it according to directions — one pound of the soap to ten gallons of water — and it was impossible to kill the bugs with it except by drowning; and they would swim in it an unaccountably long time before they would die. I then doubled the strength, using one pound of the soap to five gallons of water. After immersing one of them in this twice, he would get dry and fly away; but by keeping him wet with it for ten minutes, it would finally kill him. I am inclined to believe that it will not

kill insects or keep them off the trees, unless made strong enough to kill the trees also. I thoroughly saturated several rows of trees with it at the strength above stated, and three hours afterward found the bugs as thick as ever, and sucking away at the buds and leaves as if nothing had happened.

Tobacco.— The use of tobacco decoction was suggested by Harris in 1841, and this recommendation has been repeated by several later writers. Schöyen (1903) reports unsatisfactory results from the use of this material. Webster (1888) states that tobacco smoke was successfully used against the nymphs and the adults of the tarnished plant-bug in a greenhouse where they were working on chrysanthemums. Murtfeldt (1890 b) states that she was able to drive the bugs from a few chrysanthemum plants by dusting the plants with a tobacco preparation.

Miscellaneous.— Quassia water was recommended by Riley in 1870. He also advised the use of vinegar. Harris (1841) suggested the use of walnut-leaf decoction, and also potash water. Schöyen (1903) reports unsuccessful results from the use of milk of lime.

Deterrents

Harris (1841) advised dusting the plants with unslaked lime or with sulfur. This treatment has been occasionally recommended by later writers.

Dusting the plants with ashes has been advised by Felt (1900), Sanderson (1902), and Reh (1913).

Mechanical methods

Many writers, realizing the inefficiency of both contact insecticides and deterrents, have recommended catching the insects in various ways:

Jarring.— Jarring the insects into pans containing a little soapsuds or kerosene has often been tried. In a few instances satisfactory results have been reported, especially in those cases when the bugs were attacking the opening buds of fruit trees. It is stated that the work should be done in the early morning, while the insects are sluggish. This method may be of possible value in small plantings, but usually a fresh supply of bugs from the surrounding fields would take the place of those captured.

Insect net.— Catching the bugs in an ordinary insect or butterfly net has often been recommended. An unsuccessful attempt to employ this method in a nursery is described on page 491.

Miscellaneous.— Davis (1893) suggested the use of a hopperette for catching the adult tarnished plant-bugs. Haseman (1913) states that thousands of adults are caught on sticky shields such as are used for capturing the apple leaf-hopper. Our unsuccessful experiments with a similar device are described on page 495.

Cultural practices

Clean cultivation, in order to reduce as much as possible the number of wild plants on which the tarnished plant-bugs breed, has been commonly recommended in the past. The nursery in which our experiments of the past two years were conducted is about a square mile in extent, and is thoroughly cultivated every week or ten days throughout the growing season. No weeds of any size are ever allowed to grow in the blocks. In spite of this all parts of the area are about equally infested with tarnished plant-bugs. We are therefore of the opinion that this method of control will be found of little or no value. In fact, clean cultivation may have an entirely undesirable effect, by forcing the bugs to attack the cultivated plants when thus deprived of their natural food-plants. In all cases that have come under our observation there is always a sufficient breeding area near by to produce an abundance of bugs to infest the plants. The use of trap crops, whereby the bugs may be lured from their destructive work on cultivated plants, has been recommended by several writers. The only actual experiment with trap crops that we have been able to find was made by Wier in 1872. He says: "It has been suggested to plant early-starting succulent vegetables, such as cabbages, turnips, et cetera, among trees which we wish to protect. I have tried some of these and find them of little benefit."

Growing plants in shade.— Witte (1893) states that chrysanthemums grown in the shade are less subject to attack; and Arnold (1913) has observed that asters grown in the shade of an old apple orchard were similarly benefited. In 1912 Arnold recommended that late asters be grown under cheesecloth, as Connecticut farmers grow tobacco.

Control on peach nursery stock

Difficulty of the problem.— The control of the tarnished plant-bug on peach nursery stock presents peculiar difficulties. The injury is done within a few days by the active, winged adults that invade the peach blocks in countless swarms from surrounding meadows. They are extremely shy and take flight at the slightest alarm, making it practically impossible to hit them with a spray. They are provided with a tough, impervious integument which renders them resistant to the strongest contact insecticides that it is possible to use on the peach foliage. Furthermore, the location of the average nursery is such that even if all the bugs on the stock could be destroyed their numbers would soon be replenished by new invasion from the surrounding fields.

Previous recommendations.— As stated above, Phillips (1906) attributed this injury to a mite, but the remedial measures employed by him would apply equally well if the injury were caused by the tarnished plant-bug.

He attempted to assist the tree to outgrow the injury by judicious pruning in May and June. On May 18 injured trees were pruned by pinching off the terminal bud, which had ceased to grow, giving one of the side shoots near the tip an opportunity to push up almost straight. The tips of the other laterals were also pinched off so as to throw the growth into the bud that was left at the top. On August 15 an examination showed that of the pruned trees 68 per cent and 73 per cent of Wonderful and Champion, respectively, had grown straight. Unfortunately no check is available for comparison, and it is also to be noted that only 13 per cent of the total number of trees were injured in the first place — which is a very much smaller percentage of injury than is common in nurseries in New York. On June 22 other trees of an unknown variety were similarly pruned, except that some of the lower laterals were cut off close to the trunk. In this case only twenty-five trees were treated. By the 15th of August 88 per cent of the pruned trees had grown up straight.

Back and Price (1912) state that this method of pruning is worthless during the period of greatest activity of the tarnished plant-bug, for as fast as a new shoot is formed the terminal bud is killed. On the other hand, Quaintance (1912) quotes a letter from a Maryland nursery firm in which the following statement is made:

> The past summer we kept a gang of men going over our peach blocks and cutting or heading-in the side branches in order to throw the growth to the terminals and make them start a second growth. In this way we got our trees to start to grow and the most of them finally outgrew the trouble. We knew no other remedy than to cut the side branches back two or three inches.

Haseman (1913) recommends the destruction of all weeds on which the nymphs develop and the elimination of hibernating quarters, and suggests the use of sticky shields for catching the adult bugs. The latter recommendation is based on the observation that many of the bugs are caught on sticky shields such as are used for capturing the apple leaf-hopper.

EXPERIMENTS IN NEW YORK

In 1895 Professor Slingerland conducted rather extensive experiments in the use of an ordinary insect net for catching the bugs by sweeping the nursery stock. For several weeks in that season a boy was kept constantly employed in this way in a nursery at Geneva, New York. It was found that, although great numbers of the insects were captured, little real good was accomplished, as new bugs kept coming in from the surrounding fields to take the place of those destroyed, and the plan was abandoned.

In 1912, when this work was resumed, thinking that the insects might be killed with contact insecticides we first tried various substances on a small scale, as follows:

Soap

On June 29 Mr. Snodgrass used Vreeland's Electro Insecticide soap, 1 pound in 5 gallons of water. Adults and nymphs of all stages were sprayed. The nymphs, if well wet with the spray, were killed. The adults, however, if sprayed on the back only, were not injured, but if the spray was heavy enough to drench them so that they were wet on the underside of the body they succumbed in every instance in about half a minute. In 1913, on June 26, we repeated this experiment, using the soap at the same strength. Adults were released on a piece of canvas and were thoroughly sprayed. In two minutes they were all apparently dead. We placed them in a small wooden box, and at the end of twenty minutes all were active and had apparently fully recovered and they flew away. In a subsequent experiment we did succeed in killing two adult tarnished plant-bugs by so thoroughly drenching them with the solution that they were practically drowned.[3] Foliage tests showed that this brand of soap, 1 pound in 5 gallons of water, can be safely used on peach nursery stock. This is doubtless due to the fact that it contains practically no free or uncombined alkali.

Nicotine

Preliminary foliage tests showed that homemade tobacco decoction could not be safely used on the peach foliage. This was not the case, however, with "Black Leaf 40" tobacco extract, which can be safely used on peach nursery stock at any strength that would be warranted by the expense incurred. Unfortunately, however, "Black Leaf 40," either alone or with the addition of a little soap, as is commonly recommended in order to make it stick and spread better, was not effective against adult tarnished plant-bugs. On August 15, 1911, we used "Black Leaf 40," 1 part in 800 parts of water, adding soap at the rate of 2 pounds in 50 gallons. Two fourth-stage nymphs were sprayed until they were thoroughly drenched; one died, the other recovered. An adult was thoroughly wet twice, but recovered and flew away.

On June 26, 1913, we tried "Black Leaf 40" tobacco extract, 1 part in 500 parts of a solution of Electro Insecticide soap—1 pound in 5 gallons of water. We sprayed a number of adults very thoroughly, confining them on a piece of canvas. It took them one to two minutes to succumb to the effects of the insecticide. In fifteen minutes all had recovered and were able to fly except two, which had apparently drowned in a puddle of the liquid.

Kerosene emulsion

On June 29, 1912, Mr. Snodgrass experimented with a 15-per-cent kerosene emulsion, with results similar to those obtained with the soap solution.

[3] In this connection it is of interest to compare the experience of Mr. Ayers, as given on page 488.

From the above experiments we were convinced that the use of contact insecticides for killing the tarnished plant-bugs on peach nursery stock is entirely out of the question. It would doubtless be feasible to kill the nymphs in this way, but they do practically none of the damage.

We were aware all the time of the difficulty of hitting the lively adults with any spray, but had hoped, provided a satisfactory spray could be devised, to reach them by spraying at night, when the bugs were asleep on the nursery trees.

Asafetida

Thinking that this ill-smelling substance might have a deterrent effect on the bugs, we sprayed a small patch of wild mustard on June 25, 1913, where the bugs were extremely abundant, using a 20-per-cent solution of tincture of asafetida diluted 1 ounce in 50 ounces of water. On the next day there was no appreciable odor left on the plants, and there were apparently as many bugs present as before.

Dusting experiments

As long ago as 1841, Harris suggested that lime or sulfur sprinkled on the plants might be distasteful to the bugs and so prevent their injuring the plants. When we found that it was practically impossible to kill the adult bugs with contact insecticides, we naturally turned to this method of control and attempted to protect the peach trees by dusting them with lime and sulfur, land plaster and sulfur, and land plaster. In applying this dust we met with unexpected difficulties. At first we tried to use a small hand duster, Leggett's Brownie duster, such as is shown in Fig. 75; but we soon found that such a machine was entirely inadequate for dusting a large number of trees and it was discarded. Next we procured a dusting machine made by the Kansas City Dust Sprayer Manufacturing Company, but we experienced considerable difficulty in devising a means for carrying it through the nursery rows. We finally mounted it on top of a large nursery spray-rig, and then found that when the dust was thrown from a stationary tin pipe it seemed to settle almost everywhere except on the tips of the leaders, where it was most needed. After experimenting with various arrangements of tin piping with flexible joints, all of which were failures, we conceived the idea of using a piece of two-inch rubber suction hose. This was flexible and could be easily directed down on the tips of the leaders. Still, even with this arrangement, there was great waste of material, as most of the dust went on the ground and the lower leaves, and very little on the tips of the leaders. This method, moreover, was too expensive, requiring a team and a driver, one man to run the duster, one to direct the hose, and one to mix the material. It was therefore abandoned

for a much simpler and less wasteful method. Tin quart milk cans, with the bottom perforated with a large number of nail holes, were used as a kind of pepperbox, and the dust was applied directly to the tips of the leaders (Fig. 71). In this way it was comparatively easy to make the applications and the waste of material was greatly lessened.

TABLE 1.— RESULTS OF DUSTING EXPERIMENTS

		Number of injured terminals on July 2	Number of injured terminals on July 6	Number of injured terminals on July 10
Experiment with lime and sulfur dust	Row 1....	96	208	260
	Row 2....	83	202	267
	Row 3....	93	232	363
	Total...	272	642	890
	Check 1...	88	220	340
	Check 2...	78	190	291
	Check 3...	100	240	315
	Total. .	266	650	946
Experiment with land plaster and sulfur dust	Row 1 ..	88	216	360
	Row 2 . .	85	291	305
	Row 3....	92	224	297
	Total...	265	731	962
	Check 1. .	70	220	220
	Check 2...	92	200	360
	Check 3. .	94	205	352
	Total...	256	625	932
Experiment with land plaster dust alone	Row 1...	88	202	302
	Row 2....	106	197	330
	Row 3....	120	215	312
	Total...	314	614	944
	Check 1...	86	200	268
	Check 2...	75	195	270
	Check 3...	56	190	373
	Total..	217	585	911

The materials used were as follows: flowers of sulfur and hydrated lime in equal parts; flowers of sulfur and land plaster in equal parts; and land plaster alone. Three rows, containing about six hundred trees each, were dusted with each preparation, and an equal number of rows were left as checks. The injured leaders on these rows were counted

on July 2, and the application was made on the same day with the milk-can "pepperboxes." During the dusting, and for several days following, there was a high west wind which whipped the tops of the trees about and shook off nearly all the dust. On July 6 the number of injured terminals was again counted and the trees were redusted. The wind continued, and on the following day there was a sharp shower that washed off the dust. On July 8 the trees were redusted and on July 10 the injured terminals were again counted. The result of the counts is shown in Table 1.

The dusting was then discontinued, owing to the fact that by July 12 practically all the terminals showed some injury on both the dusted and the undusted rows.

Sticky shields

Haseman (1913) states that sticky shields, such as are used for the apple leaf-hopper, catch thousands of tarnished plant-bugs when drawn through the nursery rows. Thinking that some such device might be used to advantage in the peach blocks, we constructed two wire screens on light wooden frames about 7 by 2½ feet in size. The screen used was ordinary wire mosquito netting. The shields were thoroughly smeared with "tree tanglefoot," and were carried along the rows by two men as shown in Fig. 76.

TABLE 2.— NUMBER OF TARNISHED PLANT-BUGS PER ROW CAUGHT WITH STICKY SHIELDS, ON JUNE 26 AND 27

Row	Leeward screen	Windward screen
1	18	2
2	3	3
3	2	2
4	2	2
5	3	1
6	2	2
7	4	1

In an attempt to increase the efficiency of the screens, small peach branches were tacked on the ends so as to stir up the bugs and cause them to take flight. Also the windward screen was discarded, and one of the operators used a leafy branch in its place in an attempt to drive the bugs onto the screen. The two screens were carried over the rows at different speeds. In spite of all these modifications we were unable to increase the efficiency of the device and it was finally discarded.

Suction apparatus

In 1910 Mrs. M. E. Sherman published in the California Cultivator an interesting account of a machine invented by C. B. Driver, of Dinuba, California, for capturing grape leaf-hoppers by air suction (Fig. 74). This device consists of a rotary fan driven by a gasoline engine, which produces a strong draught somewhat on the principle of a vacuum cleaner. In order to confine the insects to the vicinity of the intake and to increase the distance from the opening at which the suction can operate, the machine is provided with a canvas canopy extending over the row, from which hang canvas curtains in front, behind, and on the side. It is reported that this machine has been successfully used in fighting the grape leaf-hopper.

Thinking that some such machine might be used for catching tarnished plant-bugs, we made a few preliminary experiments with a planing-mill blower. A blower made by the American Blower Company, with a 30-inch fan, was used, attached to a 4-horse-power gasoline engine. We did not attempt to mount this on wheels for carrying it through the rows, because of the expense involved. With this machine we were not able to get enough suction over an opening 8 inches in diameter to draw in bugs resting on the hand and held at the mouth of the pipe. But we found that if bugs were thrown into the pipe they were torn to pieces by the fan and no additional killing device would be necessary.

Even if it were possible to construct a suction machine that would draw in the adult bugs from the trees, such a machine would necessarily be so heavy that it would be very difficult to mount it so that it could be drawn through the nursery rows. The rows are so close together — about four feet — that it would not be possible to have both wheels of the rig between two adjacent rows. If a wider rig were used, with one wheel in one row and the other wheel in the next, the rig would have to be so high that with the blower in position it would be top-heavy. If the wheels were still farther apart, so as to include two rows, the blower and engine might be underslung in the vacant row. This arrangement is used in some nursery sprayers, but in the case of the blower the apparatus would be so heavy as to make it unwieldy. In the face of these difficulties we concluded that this method of catching the bugs is impracticable and it was therefore abandoned.

Molasses

It was suggested that tarnished plant-bugs might be attracted to molasses. Accordingly on July 25, 1913, two shallow tin pans, 14 by 6 inches in size, were placed in the peach block on benches about on a level with the top of the seedlings. About three quarters of an inch of molasses

was placed in the bottom of each pan. By August 19, when the experiment was abandoned, only a single tarnished plant-bug had been captured. Other insects were caught in abundance, particularly small moths, many flies, several species of ground beetles, and a number of carrion beetles which were doubtless attracted by the decomposing remains of two field mice that had been caught in the molasses.

SUGGESTIONS FOR FUTURE EXPERIMENTAL WORK

The foregoing experiments show that it is doubtful whether the injuries to peach nursery stock by the tarnished plant-bug can ever be prevented by the use of deterrents, or whether the adult bugs can be killed under actual field conditions by any contact insecticide now at our disposal. Catching the bugs by mechanical means has thus far been unsuccessful. Furthermore, either catching or killing the bugs in the nursery would be of very little value in protecting the trees, because of the invasion of the blocks by swarms of bugs from adjoining fields. It would seem that the only feasible means of preventing the injury to the trees would be either by excluding the adults from the nursery blocks by a wire screen fence, or by enclosing the tips of the terminals in bags during the period in which most of the injury is inflicted. It might also be possible to prevent some of the loss from this cause by assisting the trees to outgrow the injury by proper pruning and cultural methods.

Fencing

In order to determine the feasibility of using a fence for excluding tarnished plant-bugs from peach blocks, the following preliminary experiments were performed: After unsuccessful attempts to use a cloth mosquito-netting fence — which was readily torn by the wind — on July 31, 1913, we erected a wire-cloth fence varying in height from 5 feet 2 inches to 6 feet and inclosing an area about 42 feet square. The cloth had about twelve meshes to the inch. At this time practically all the terminals had been injured, and the object was merely to determine whether or not the bugs would get over the fence. No bugs were seen to actually fly over, but it was found that they would alight on the wire cloth, crawl up to the top, and then take flight, often alighting within the inclosure. In one case an adult was seen to crawl through one of the meshes, but this probably occurs only rarely. As a rule the bugs do not fly much higher than the tops of the nursery stock. In order to determine the direction of flight, a number of bugs were released from an insect net held waist high, about twenty feet to the windward of the fence. A gentle breeze was blowing. The bugs flew with the wind, and the greater number alighted on the fence at about the same height

or slightly higher. Some flew almost directly downward onto the peach seedlings. It was a common observation that whenever the adults took flight from the nursery trees their flight was not more than a few yards, at most, and they rarely rose more than a foot or so above the tips.

From these observations we are convinced that there is little danger of any number of bugs flying over such a fence; but it is probable that many would crawl to the top and fly into the inclosure. The latter difficulty might be overcome by putting a band of "tanglefoot," about a foot or so wide, around the top of the fence, smearing it on the wire cloth. Such a device is worthy of further trial and we plan to test it in another season. In order to be effective such a fence should be in position before June 20, for, according to our observations, the bugs do not occur in the peach blocks in any considerable numbers until shortly after that date.

Bagging

Since it is necessary only to protect the leaders from injury, and since the stinging of the tips of the laterals does not affect the commercial value of the trees, it might be advisable to bag the terminals on about June 20, leaving the bags on for about four weeks or until the leader has made sufficient growth. We have not as yet been able to test this in the field at the proper season, but we have experimented with different kinds of bags in order to determine their effect on the foliage in July and August.

On July 12, 1913, we covered about two dozen terminals with unglazed yellow paper bags, tying them at the bottom with string. Equal numbers of one-, three-, five-, and ten-pound bags were used. On July 19 the bags were examined, and apparently the growth of the tips had not in any way been impeded. The ten-pound bags, however, had bent the tips over and the one-pound bags had somewhat cramped the growth of the foliage. The five-pound bags seem to have proved the most satisfactory. In spite of a heavy wind in the early part of the week, followed by sharp showers, the bags were still in good condition. On July 26 we put on eight more five-pound paper bags, eighteen mosquito-netting bags, and seven cheesecloth bags, all of about the same size as the five-pound paper bags. The ten-pound bags at this time had bent a few of the tips far over to the leeward. On July 31 a new lateral had started under one of the paper bags and was producing a healthy growth. The foliage inside the five-pound bags was doing well, but that inside the one-pound bags was much cramped. The leaders on which the ten-pound paper bags were used were bent over still more than at the time of the last observation. The cheesecloth bags had settled down about the foliage, although there had been no rain since the fifteenth or sixteenth of the month. The mosquito-netting bags remained fairly free of the foliage.

There was rain on August 10; on the next day the bags were examined and it was found that the cheesecloth and the mosquito-netting bags had settled down badly on the foliage. In the case of the latter the new growth was pushing out between the meshes and could easily have been stung if the tarnished plant-bug had been present. The ten-pound bags had bent their tips completely over. The bagged tips were all somewhat bent over to the eastward, due to prevailing west winds, although all the trees showed a tendency toward this condition. Although the foliage in the five-pound paper bags was a little crowded, apparently healthy growth was taking place in all. On October 11 the bags were removed and at this date the following conditions were observed:

Cheesecloth bags.— Under these the leaves were healthy, but the wood was immature; in one bag the leaves were dead.

Paper bags.— Under most of these the tips had an immature appearance.

Mosquito-netting bags.— In these, as a rule, the tips were immature, but less so than the tips under the cheesecloth bags. In one or two cases the tips were stunted and the leaves wilted, but this may have been due to red-spider injury, as the leaves under all the bags were badly infested with this mite.

Of course these bags were in place at a season of the year different from that which would be necessary in order to protect them from tarnished plant-bug injury, and moreover they were kept on for a much longer time than we believe would be required for that purpose. However, this experiment indicated that apparently the bagging of the tips would not seriously injure their growth.

The bags could be put on more quickly by the use of pins than by tying. The cost of the bags and the labor of putting them on would not be great. This method of protecting the tips deserves further trial.

Pruning

It would also be worth while to experiment with various methods of pruning the injured trees in order to help them outgrow the injury, as discussed on page 491.

Cultural practices

It is a common observation that where peach nursery stock is grown on soil best adapted for that purpose, and where it receives proper cultivation at the proper time, the trees are more likely to outgrow the injury. Trees are less likely to recover in seasons of drought or when grown on land that is not properly drained, for under these conditions the trees do not receive the proper amount of moisture. Under some circumstances it might be advisable to apply some quick-acting fertilizer to stimulate the growth of the trees, and thus help them to overcome the injury.

INDEX TO THE TARNISHED PLANT-BUG IN LITERATURE

(References marked with an asterisk have not been verified)

Amyot, C. J. B.

1846 Entomologie française. Rhyncotes. Soc. Ent. France. Ann., 152–153 (204–205).
Description.

Arnold, G.

1912 How to grow asters. 6th ed. James Vick's Sons, Rochester, New York. P. 24–26, fig. 6–7, pl. on p. 27, 29, 31.
Description of injury to asters; also mentions injury to *Brachycome*, *Calendula*, *Centaurea cyanus* and *C. moschata*, *Acroclinium*, *Helichrysum*, *Tagetes*, *Antirrhinum*, *Salvia*, and *Dahlia*; recommends air-slaked lime, whale-oil soap, and kerosene emulsion, and suggests growing plants in shade and under cheesecloth.

1913 The tarnished plant-bug on the aster. Florists' exchange **36**:11:576.
Records injury to asters and dahlias at Rochester, New York, and describes experiments by Faulwetter proving that *Lygus pratensis* is the cause.

Atkinson, E. T.

1889 Catalogue of the Capsidae. Asiatic Soc. Bengal. Journ. sup. **58**:2:90–91.
Synonymy and distribution.

Back, E. A., and Price, W. J.

1912 Stop-back of peach. Journ. econ. ent. **5**:329–334.
General account of injury to peach nursery stock; experiments to prove that *Lygus pratensis* is the cause.

Baerensprung, F. von

1860 Hemiptera heteroptera Europae systematice disposita. Berliner ent. zeitsch. **4**:15.
Lists insect.

Baldwin, C. H.

1912 Indiana State Ent. Ann. rept. **5**:129–130, one plate.
Brief general account; recommends clean culture and 10-per-cent kerosene emulsion.

Banks, N.

1910 Catalogue of the Nearctic Hemiptera-Heteroptera. Amer. Ent. Soc., p. 46.
Insert listed, with brief synonymy.

1912 New American mites. Ent. Soc. Washington. Proc. **14**:98–99, pl. 11, fig. 16.
Description of *Tarsonemus waitei*, to which writer attributes injury to the buds of peach nursery stock.

Barker, M.

1895 Cornell Univ. Agr. Exp. Sta. Bul. 91:189–190.
Brief account of tarnished plant-bug as a chrysanthemum pest; recommends pyrethrum, kerosene emulsion, and hand picking.

Behrens, J.

1904* Die hopfenwanze. Landw. Ver. Baden. Wochenblatt, 692–693.

1906* Verursacht unfruchtbarkeit des hopfens. Landw. Vers. Anst. Augustenberg. Bericht **1**:——.

Bethune, C. J. S.

1909 Ontario Agr. Dept. Bul. 171:7, fig. 15.
Brief general account.

Blanchard, C. É.

1840 Histoire naturelle des insectes **3**:137–138.
Brief synonymy and description.

Blatchley, W. S.

1895 Notes on the winter insect fauna of Vigo county, Indiana — III. Psyche **7**:279.
Brief note; records hibernation under mullein leaves.

Bolivar, ————.

——* Soc. Esp. Anales **10**:——.

Britton, W. E.

1905 Connecticut State Ent. Rept. **4**:218–219, fig. 9.
Reports injuries to dahlias and tobacco; recommends kerosene emulsion.

1907 Connecticut State Ent. Rept. **6**:276.
Records supposed injury to tobacco.

1914 Connecticut State Ent. Rept. **13**:256.
Mentions injury to potatoes and dahlias.

Bruner, L.

1891 a Nebraska Agr. Exp. Sta. Bul. 16:67, fig. 15.
Copies Riley's figure of the adult.

1891 b U. S. Bur. Ent. Bul. 23 o. s.:16.
Insect mentioned as destructive to beets.

1893 The insect enemies of small grains. Nebraska State Agr. Bd. Ann. rept. **1893**:447, fig. 78.

1894 Insect enemies of the apple tree and its fruit. Nebraska State Hort. Soc. Ann. rept. **1894**:162, 177, fig. 16.
Brief general account; recommends clean culture and kerosene emulsion.

1895 Insect enemies of the grape vine. Nebraska State Hort. Soc. Ann. rept. **1895**:99, fig. 23.
Brief note; recommends clean culture and kerosene emulsion.

1899 Insect enemies of the apple tree and its fruit. Nebraska State Hort. Soc. Ann. rept. **1898**:155–156, fig. 25.

Records injury to apples, and recommends kerosene emulsion and clean culture.

1900 Insect enemies of the stone fruits. Nebraska State Hort. Soc. Ann. rept. **1900**:104, fig. 60.

Brief account; recommends clean culture and kerosene emulsion.

Burmeister, H.

1835 Handbuch der entomologie **2**:270–272.

Description.

Card, F. W.

1903 Bush-fruits, p. 235–254, fig. 32.

Brief general account; mentions injury to strawberries and blackberries; recommends pyrethrum, kerosene emulsion, and use of insect net.

Chittenden, F. H.

1903a A brief account of the principal insect enemies of the sugar beet. U. S. Bur. Ent. Bul. 43:52–54, fig. 51–52.

General account; recommends kerosene emulsion, pyrethrum, use of insect net, clean culture.

1903b The principal insect enemies of the sugar beet. U. S. Agr. Dept. Rept. **74**:202–204, fig. 51–52.

Same as above.

Chittenden, F. H., and Marsh, H. O.

1910 Note on the oviposition of the tarnished plant-bug. Journ. econ. ent. **3**:477–479.

Notes on oviposition and nymphal instars.

Cockerell, T. D. A.

1893 The entomology of the mid-alpine zone of Custer county, Colorado. Amer. Ent. Soc. Trans. **20**:363.

Lists insect.

1894 Notes from New Mexico. Insect life **7**:210.

Records the insect as abundant on alfalfa.

1895 New Mexico Agr. Exp. Sta. Bul. 15:66, 71.

Records sweeping adults from alfalfa by moonlight and daylight.

Collinge, W. E.

1912 Remarks upon an apparently new apple pest, *Lygus pratensis* Linn. Journ. econ. biol. **7**:64–65.

Describes oviposition in young apple fruit.

Comstock, J. H.

1888 Introduction to entomology, p. 206–207.

Brief general account; suggests jarring.

Cook, A. J.

1876a A new insect enemy. Michigan farmer, July 25.

Records injury to wheat, corn, potatoes, and currants; suggests clean culture.

1876b Same, reprinted. Cultivator and country gentleman **41**:531.

Cooley, R. A.

1900 Montana Agr. Exp. Sta. Bul. 23:96–97.

Reports the insect destructive to strawberries in the Bitter Root Valley. Injured asters and fruit trees at station. Passes the winter in immature condition under any convenient shelter. Eggs are deposited on stems of plants. Jarring recommended.

1904 Montana Agr. Exp. Sta. Bul. 51:256–257.

Brief statement of injury to strawberries and to nursery stock; recommends jarring.

1905 Montana Agr. Exp. Sta. Ann. rept. **12**:270, fig. 14.

Records general occurrence of the insect in Montana.

Curtis, J.

1840 Farm insects, p. 436, pl. O, fig. 27.

Records occurrence on potato.

1849 Observations on the natural history and economy of various insects affecting the potato-crops, including plant-lice, plant-bugs, frog-flies, wireworms, millipedes, mites, beetles, flies, et cetera. Roy. Agr. Soc. England. Journ. **10**:79–81, fig. 27.

Records injury to potatoes by *Lygus umbellatarum.*

Davis, G. C.

1893 Michigan Agr. Exp. Sta. Bul. 102:10–13, fig. 6.

Account of injuries to celery caused by the insect. Recommends kerosene emulsion, clean culture, hopperette.

1896 Michigan Agr. Exp. Sta. Sp. bul. 2:15, fig. 6.

Reports attacks on carnations. Recommends kerosene emulsion, fir-tree oil, or whale-oil soap.

1897 Report of the Consulting Entomologist. Michigan Agr. Exp. Sta. Ann. rept. **9** for 1895–1896:136.

Describes injury to beans in Michigan caused by the tarnished plant-bug, and recommends clean culture.

Dean, G. A., and Peairs, L. M.

1914 Kansas Agr. Col. Extension Div. **6**:2:66.

Brief account; authors recommend clean culture

Distant, W. L.

1884 Biol. Centr. Amer. Rhynchota. Hemiptera-Heteroptera **1**:272–273, tab. XXIII, fig. 4, 6, 7, 16.

Synonymy and distribution.

Douglas, J. W., and Scott, J.

1865 British Hemiptera **1**:463–466.

Description and synonymy.

Dwigubsky, J. A.

1802* Primitiae faunae mosquensis, seu enumeratio animalium quae sponte circa mosquam vivunt.

Eberhart, N. M.

1888 Outlines of economic entomology, p. 58–59, fig. 63.

Brief general account; recommends pyrethrum and kerosene emulsion.

Essig, E. O.

1913 California State Hort. Com. Monthly bul. **2**:148, fig. 130.

Brief general account; recommends emulsions, soap washes, tobacco sprays, resin washes, clean culture.

Fabricius, J. C.

1775 Systema entomologiae, p. 724.

Description.

1787 Mantissa insectorum **1**:303.

Brief description.

1794 Entomologia systematica **4**:171.

Description.

1803 Systema rhyngotorum, p. 234–235.

Description of *Lygaeus campestris* and *L. pratensis*.

Fallen, C. F.

1807 Monographia cimicum Sveciae, p. 83, 84, 86.

Description.

1818 Monographia cimicum Sveciae, p. 83, 84, 86.

1829 Hemiptera Sueciae, p. 90–91.

Description.

Felt, E. P.

1898 Insects on chrysanthemums. American gardening **19**:639.

Records injury to chrysanthemums.

1900 Illustrated descriptive catalogue of some of the more important injurious and beneficial insects of New York State. New York State Mus. Bul. 37:30–31, fig. 53.

Records injury to peach nursery stock, and recommends hand picking, dusting with ashes, and burning rubbish in the fall.

1904 New York State Ent. Rept. **19** for 1903:144–145.

Records injury to asters, and recommends whale-oil soap — one pound to nine gallons of water — and clean culture.

1905 Gnarled pears. Country gentleman **70**:766, 885.

Injury to pears caused, possibly, by the feeding punctures of the tarnished plant-bug.

1909 Apples injured by insects. Country gentleman **74**:859.
Describes injury to apples and attributes it to *Lygus pratensis*.

1910 a New York State Ent. Rept. **25**:90.
Reports supposed injury to apple fruit.

1910 b Deformed apples. Country gentleman **75**:82.
Brief account of deformed apples; injury attributed to the egg-laying punctures of the tarnished plant-bug; clean culture recommended.

Fieber, F. X.

1861 Die Europäischen Hemiptera, p. 273.
Description of *Lygus pratensis* and *L. campestris*.

Fletcher, J.

1894 a Injurious insects of the year. Ent. Soc. Ontario. Ann. rept. **24**:10, fig. 3.
Note; suggests beating.

1894 b Canadian Exp. Farms. Rept. Ent. and Bot. **1893**:180–181, fig. 20.
Brief note.

Flor, G.

1860 Die Rhynchoten Livlands in systematischer folge beschrieben **1**:517–521.
Description and bibliography.

Forbes, S. A.

1884 a The tarnished plant-bug. Farmers review, Feb. 28, p. 150.
General account; mentions injury to potato, strawberry, raspberry, blackberry, and nursery stock, and suggests the possibility that the tarnished plant-bug is a carrier of fire blight of pear and apple; recommends jarring, pyrethrum, and kerosene emulsion.

1884 b Wisconsin State Hort. Soc. Trans. **13**:21–25, fig. 10–14.
General account; describes injury to strawberries; recommends clean culture, insect net, pyrethrum, and kerosene emulsion.

1884 c The tarnished plant-bug. Minnesota State Hort. Soc. Ann. rept. **1884**:339–342.
General account; recommends clean culture, shaking bugs into soapsuds or kerosene and water, insect net, pyrethrum, and kerosene emulsion.

1884 d Illinois State Ent. Rept. **13**:10, 62, 115–135, pl. XI–XIII.
General account; discusses injury to strawberries; suggests clean culture and use of insect net, and records experiments with pyrethrum and kerosene emulsion.

1884 e Supplementary report on insects affecting the strawberry. Mississippi Valley Hort. Soc. Trans. **2**:240.
Brief general account; recommends clean culture, pyrethrum, and kerosene emulsion.

1885 Illinois State Ent. Rept. **14**:79–80; pl. VII, fig. 2; pl. VIII.
Records injury to strawberries; describes egg; suggests trap crops and pyrethrum.

Forbes, S. A., and Hart, C. A.

1900 Illinois Agr. Exp. Sta. Bul. 60:438–440, fig. 18–19.

General account of life history. The insects pass the winter both as adults and nymphs. Authors recommend burning trash in cold weather; kerosene emulsion. Figure of adult and older nymph.

Fourcroy, A. F.

1785 Entomologia parisiensis, p. 205.

Description.

Garman, H.

1890 Kentucky Agr. Exp. Sta. Bul. 31:26–27, fig. 8.

General account of insect as a strawberry pest. Recommends pyrethrum and kerosenet [*sic*], and mentions a fungous parasite.

1894 Same, reprinted. Kentucky Agr. Exp. Sta. Ann. rept. 3 for 1890:171–172, fig. 8.

Gaumer, G. F.

1876 The tarnished plant-bug. Kansas farmer, May 10.

General account; mentions injury to apple fruit, pear, and cherry; recommends jarring, tobacco water, and solutions of air-slaked lime, sulfur, and cresylic soap.

Geoffroy, E. L.

1764 Histoire abrégée des insectes, p. 451–452.

Description.

Georgia State Department of Agriculture

1898 Publications for 1898, **24**:438–439.

General account of insect as a pear pest; clean culture and jarring recommended.

Gibson, A.

1913 Report on insects for the year. Ent. Soc. Ontario. Ann. rept. 43 for 1912:17, fig. 10.

Mentions injury to dahlias

Gillette, C. P., and Baker, C. F.

1895 Colorado Agr. Exp. Sta. Tech. bul. 1:36.

Lists insect.

Glover, T.

1876 U. S. Comm. Agr. Rept. 1875:126, fig. 34.

Brief note.

Goeze, J. A. E.

1778 Entomologische beiträge zu des Ritter Linné zwölften ausgabe des natursystems **2**:279.

Description.

Gossard, H. A.

1905 Ohio Agr. Exp. Sta. Bul. 164:4.
Brief mention; recommends clean culture.

1908 Ohio Agr. Exp. Sta. Bul. 198:76.
Brief general account; mentions injury to strawberries; suggests kerosene emulsion made with pyrethro-fish-oil soap.

Hahn, C. W.

1831 Die wanzenartigen insecten **1**:217–220, pl. XXXV, fig. 112–113; 3:81, pl. XCIX, fig. 301.
Description and brief synonymy.

Harris, T. W.

1841 A report on the insects of Massachusetts injurious to vegetation, p. 161–164.
General account; records injury to dahlias, marigolds, asters, balsam, and potatoes; suggests soapsuds, potash water, tobacco and walnut-leaf decoction, lime and sulfur dust, irrigation, poultry.

1851 a Insects on the potato-vine. Journ. agr. **1**:99–102.
Records injury to potatoes.

1851 b Salem observer **29**:2.
Mentions insect as injurious to potato.

1852 A treatise on some of the insects of New England which are injurious to vegetation, p. 174–177.
Same as 1841 edition.

1863 A treatise on some of the insects injurious to vegetation, p. 200–203, fig. 85. Flint edition.
Same as 1841 edition.

Haseman, L.

1913 Peach " stop back " and tarnished plant-bug. Journ. econ. ent. **6**:237–240.
Original observations on habits and life history of *Lygus pratensis;* recommends clean culture and sticky shields, and suggests the use of trap crops.

Herrick-Schaeffer, G. A. W.

1835 a Die wanzenartigen insecten **3**:81.
Description of *Capsus gemellatus.*

1835*b Nomenclator entomologicus **1**:51, 83.

Hitchings, E. F.

1907 Maine State Ent. Ann. rept. **1907**:4–5.
Reports injury to dahlia buds, and recommends kerosene emulsion and sweeping near-by shrubbery with an insect net.

1908 Maine State Ent. Ann. rept. **4**:5–7.
Records injury to dahlia, chrysanthemum, and aster buds, and to apple buds and fruit; suggests kerosene emulsion and pyrethrum as remedies.

Horvath, G.

1888* Matériaux pour servir à l'étude des Hémiptères de la faune paléarctique. Revue d'entomologie **7**:181.

Original description of *Lygus rutilans*. The species is compared with *L. pratensis*.

1901 Zoologische ergebnisse der dritten Asiatischen forschungsreise des Grafen Eugen Zichy **2**:253.

Description.

Houghton, C. O.

1909 Report on insects. Peninsula Hort. Soc. [Delaware]. Trans. **22** for 1909:38–39.

Brief account; records injury to potatoes; recommends tobacco water — one pound of stems to a gallon of water, boiled one half hour — or pyrethrum — dry, or one pound to fifteen gallons of water.

Howard, L. O.

1901 The insect book, p. 301.

Brief note; mentions injury to strawberries.

Hueber, T.

1901 Synopsis der deutschen blindwanzen **6**:117–127.

Description and extensive discussion of varieties; synonymy.

Jack, J. G.

1890 Diseases of chrysanthemums caused by insects. Garden and forest **3**:439–440, fig. 55b.

Mentions injury to chrysanthemum.

Johnson, W. G.

1898 Preliminary notes upon an important peach tree pest. Ent. news **9**:255.

Records injury to peach nursery stock attributed to a mite.

1899 Miscellaneous entomological notes. U. S. Bur. Ent. Bul. 20:63.

Records injury to pear and plum buds in a nursery, in Pennsylvania and in Maryland; states that a 15-per-cent solution of kerosene and water was used successfully.

1900 Maryland State Hort. Soc. Rept. **1899**:84.

Records injury to pear and plum nursery stock; experiments with a 15-per-cent solution of kerosene and water.

Kaltenbach, J. H.

1874 Die pflanzenfeinde aus der klasse der insekten, p. 282, 530.

Insect feeds on *Urtica* and *Pastinaca*.

Karsch, F.

1889 Oekonomisch-entomologische notizen. Ent. nachr. **15**:57.

Mentions injury to fuchsias.

Kellogg, V. L.

1892 Common injurious insects of Kansas, p. 80–81, fig. 44.

General account; recommends kerosene emulsion, pyrethrum, and jarring.

1905 American insects, p. 209, fig. 289.

Brief note; mentions injury to sugar beet, strawberry, pear, plum, apple, and quince.

Kirschbaum, C. L.

1855 Rhynchotographische beiträge, I, Die capsinen der gegend von Wiesbaden. Ver. Naturkunde Nassau. Jahrb. **10**:173, 217, 223, 224, 225, 271, 272, 273.

Brief notes and descriptions.

Kolenati, F. A.

1845 Meletemata entomologica **2**:118–119, 120.

Description.

Latreille, P. A.

1804 Histoire naturelle générale et particulière, des crustacés et des insectes **12**:221.

Brief description.

Laubert, R.

1911 Ueber eine häufige blattverunstaltung der Pelargonien. Gartenflora **60**:186–187, fig. 12.

Author mentions injury to Pelargonium which he attributes to an hemipterous nymph.

LeBaron, W.

1871 Noxious insects of the State of Illinois. First [Second] ann. rept., p. 62.

Brief account and description; recommends jarring.

Lind, J.

1911 Oversigt over haveplanternes sygdomme i 1911. Gartnertidende, December, 16 pages, figs. 1–6. Abs. in Centbl. bakt. 2:**33**:386. 1912.

The habits of the insect are discussed and a detailed description is given of injury in Denmark to apple nursery and orchard trees, pear trees, *Prunus laurocerasus*, dahlias, and chrysanthemums (*Chrysanthemum indicum* and *C. maximum*). The insect is also mentioned as being more or less injurious in Denmark to *Pyrus communis* and *P. vulgaris*, potatoes, strawberries, *Morus nigra*, *Ribes rubarum* and *R. nigrum*, hydrangea, currants, and mulberries. Hydrocyanic acid gas was successfully used against the insects in a greenhouse. For ornamental plants in the open, tobacco water and quassia water are recommended; also lime-sulfur and flowers of sulfur.

Linnaeus, C.

1746 Fauna Svecica, p. 208.

Description.

1758 Systema naturæ. 10th ed., p. 448.
Original description. Also in other editions.

1761 Fauna Svecica. Second ed., p. 253.

Lintner, J. A.

1875 Insects on potatoes. Cultivator and country gentleman **40**:472.
Records injury to potatoes.

1882 New York State Ent. Ann. rept. **1**:331.
Lists insect as feeding on apple.

1884 [No title.] Can. ent. **16**:182.
Insect mentioned as injurious to young pears.

1885 Same. Republished in Ent. Soc. Ontario. Ann. rept. **15**:13.

1886 Report of the State Entomologist to the Regents of the University of the State of New York for 1885. New York State Mus. Ann. rept. **39**:110.
Records injury to young pear fruit probably caused by *Lygus pratensis*.

1889 New York State Ent. Rept. **5**:275, 326, fig. 43.
Records injury to pear fruit attributed to *Lygus pratensis*.

1890 New York State Ent. Rept. **6**:189.
Records injury to tobacco.

1891 Beet insects. Cultivator and country gentleman **56**:577.
Describes injury to beets attributed to *Lygus pratensis*.

1893 New York State Ent. Rept. **9** for 1892:375.
Injury to beets attributed to *Lygus pratensis*.

1896 New York State Ent. Rept. **11** for 1895:270.
Lists insect as injurious to apple.

1898 New York State Ent. Rept. **13** for 1897:351–357, fig. 1.
General account and description of injury to peach nursery stock; recommends burning rubbish and jarring the bugs into a net or an umbrella; bibliography.

Lovett, A. L.

1913 Oregon Agr. Col., Ext. Div. Bul. 91 (Ext. ser. 2, no. 4): 5–6, fig. 4.
Brief general account; recommends insect net, 7-per-cent kerosene emulsion, and clean culture.

Lowe, V. H.

1900 New York (Geneva) Agr. Exp. Sta. Bul. 180:135, pl. VIII, fig. 5.
Reports injury to peach fruit in June.

Lugger, O.

1900 Minnesota Agr. Exp. Sta. Bul. 69:55–57, fig. 47.
Quotes Saunders' account; recommends clean culture and hand picking.

Mason, J. E.

1883 A list of some Hemiptera-Heteroptera of Lincolnshire, with notes on collecting. Naturalist —: 290.

Records occurrence of the insect on *Larix europæa* in England.

Meyer, L. R.

1843* Verzeichniss der in der Schweis einheimischen Rhynchoten die familie der Capsini, p. 99.

Montana State Board of Horticulture.

1908 Fifth biennial report for 1907–1908. P. 45–47, fig. 1–2.

General account; kerosene emulsion, pyrethrum, and tobacco preparations recommended.

Morrison, H.

1914 Directions for collecting and preserving insects. Indiana State Ent. Rept. 6 for 1912–1913: 119.

Copies Forbes' figures.

Murtfeldt, M. E.

1890 a Report of the Committee on Entomology. Missouri State Hort. Soc. Ann. rept. 32 for 1889: 51–52.

Records injury to pear, apricot, and quince; recommends jarring and smudging.

1890 b U. S. Bur. Ent. Bul. 22 o. s.: 75.

Records injury to apple and pear buds, strawberries, and chrysanthemums; experiment with X. O. dust. "X. O. dust consists of a mixture of finely-ground sand, lime, and tobacco, to which has been added a small amount of carbolic acid." — New Jersey Agr. Exp. Sta. Ann. rept. 11 for 1890: 527.

1902 Recent experience with destructive insects. Missouri State Hort. Soc. Ann. rept. 45: 255.

Records insect as injurious to grapes.

Nördlinger, H.

1869 Die kleinen feinde der landwirthschaft, p. 563.

Brief description.

Norman, G.

1877 Captures of Hemiptera-Heteroptera in Morayshire. Ent. monthly mag. 14: 166.

Insect listed as very common nearly all the year round.

O'Kane, W. C.

1912 Injurious insects, p. 192, 347, fig. 240.

Brief account; records injury to truck crops and apples; recommends kerosene emulsion, tobacco extract, clean culture, and jarring.

Ormerod, E. A.

1881 Manual of injurious insects, p. 102–103, 1 figure.

Brief general account of insect as hop pest; clean culture recommended.

Osborn, H.

1880 a Entomological report. Iowa State Hort. Soc. Trans. **1879:** 95–96.

General account; records injury to blossom buds of pear and apple; recommends clean culture.

1880 b The tarnished plant-bug. Western stock journal and farmer **10:**76.

Brief account of injuries to fruit in Iowa.

1884 a Iowa Agr. Col. Bul. 2:87–88.

Brief general account; recommends the burning of rubbish, and jarring.

1884 b Insects of the orchard. Iowa State Hort. Soc. Trans. **1883:**511.

Brief general account; clean culture and jarring recommended.

Osborn, H., and Gossard, H. A.

1891 Iowa Agr. Exp. Sta. Bul. 15:270.

Brief note; reports that insect feeds on purslane and weeds and attacks beets.

Oschanin, B.

1906–1909 Verzeichnis der palaearktischen Hemipteren, p. 720–723.

Synonymy and distribution.

Packard, A. S.

1869 Guide to the study of insects, p. 550.

Brief mention.

1877 Report on the Rocky Mountain locust and other insects now injuring or likely to injure field and garden crops in the western States and territories. U. S. Geol. Survey Terr. Ann. rept. **9:**755, pl. LXVII, fig. 14.

Brief general account.

Palisot de Beauvais, A. M. F. J.

1805 Insectes recueillis en Afrique et en Amérique dans les royaumes d'Oware, à Saint-Dominique dans les États-Unis, pendant les années 1781–1797, p. 187, pl. XL, fig. 7.

Description.

Panzer, G. W. F.

1793–1813 Faunae insectorum Germanicae initia oder Deutschlands insecten, p. 93, fig. 19.

Brief description and figure. This work was published in parts between 1793 and 1844. The last part published by Panzer appeared in 1813. In the copy consulted, in the New York Public Library, the work has been so bound that it is impossible to determine the date of publication of the part relating to the tarnished plant-bug.

1804 D. Jacobi Christiani Schaefferi iconum insectorum circa Ratisbonam indigenorum enumeratio systematica **3:**120, tab. CXII.

Brief description.

Parrott, P. J., and Hodgkiss, H. E.
1913 New York (Geneva) Agr. Exp. Sta. Bul. 368.
Account of *Lygus invitus*, with references to and figures of *L. pratensis*.

Patch, E. M.
1905 Maine Agr. Exp. Sta. Bul. 123:219–220.
Brief mention of insect as injuring opening leaf and flower buds.

1906 Maine Agr. Exp. Sta. Bul. 134:214–215.
Records injury to pear, aster, dahlia, celery, and potato; recommends clean culture of potato fields.

1907 Maine Agr. Exp. Sta. Bul. 148:273.
Records evidence to show that the hibernating adults are destroyed by ground beetles and rove beetles.

1908 Maine Agr. Exp. Sta. Bul. 162:364.
Records injury to potatoes.

Patch, E. M., and Johannsen, O. A.
1910 Apple-tree insects of Maine. Maine Agr. Exp. Sta. (Unnumbered bulletin.) P. 53–55, fig. 28.
Brief general account; authors recommend clean culture and jarring.

Petch, C. E.
1913 Insects of Quebec for the year 1912. Ent. Soc. Ontario. Ann. rept. **43** for 1912:73.
Lists insect as appearing in large numbers, especially on hoed crops, late in the season.

Pettit, R. H.
1900 Michigan Agr. Exp. Sta. Bul. 180:134.
Mentions insect as collected on beets.

1905 Michigan Agr. Exp. Sta. Bul. 233:6, fig. 3.
Brief mention of insect as enemy of beets; clean culture recommended.

Phillips, J. L.
1906 Virginia State Ent. and Plant Path. Rept. **5** for 1904–1905: 50–61, fig. 5–10.
General description of injury to peach nursery stock attributed to an undetermined mite; summer pruning recommended in order to produce straight trees.

Popenoe, E. A.
1874 Kansas State Hort. Soc. Rept. Comm. Ent. Trans. **1873**:123.
Mentions finding *Lygus pratensis* on apple blossoms, apparently doing some damage.

Preis, R.
1910* Tätigkeitsbericht der Versuchstation für Zuckerindustrie in Prag für das jahr 1909. Zeitsch. landw. versuchsw. Oesterr. **13**:486. Abs. in Centbl. bakt. 2:**29**:604.
Mentions insect as causing leaf spot of beets. (A letter from the magazine first referred to states that Preis did not publish this article in it.)

Provancher, L.
1886 Petite faune entomologique du Canada **3**:119.
Description.

Pugsley, M.
1880 In H. C. Raymond's report. Iowa State Hort. Soc. Trans. **1879**:230–231.
Mentions injury on potatoes, June berries, crab apples, lilacs, dicentras, and peonies.

Puton, A.
1886* Catalogue des Hémiptères Hétéroptères d' Europe.

Quaintance, A. L.
1896 Florida Agr. Exp. Sta. Bul. 34:286–288, fig. 26.
Brief general account; recommends pyrethrum, kerosene emulsion, and hand picking.

1897 Florida Agr. Exp. Sta. Bul. 42:577–581, fig. 14.
Reports that insect attacks almost all varieties of garden produce and various field crops in Florida, and causes buttoning of strawberries; recommends pyrethrum, kerosene emulsion, "Rose Leaf" insecticide.

1901 Georgia Agr. Exp. Sta. Ann. rept. **13** for 1900:361.
Brief mention of insect as occurring on alfalfa and on peach and plum buds.

1912 The peach-bud mite. U. S. Bur. Ent. Bul. 97:6:103–114.
Résumé of literature; description of injury to peach nursery stock attributed to *Tarsonemus waitei* Banks.

Rathvon, S. S.
1869 Entomology, p. 549, in J. I. Mombert's "An authentic history of Lancaster County, in the State of Pennsylvania."
Insect doubtfully listed.

Raymond, H. C.
1880 Report of Director of Third District. Iowa State Hort. Soc. Trans. **1879**:230–231.
Mentions injury to blossoms of apple, pear, plum, and cherry, and quotes letter from M. Pugsley [which see].

Reh, L.
1902 Phytopathologische beobachtungen mit besonderer berücksichtigung der Vierlande bei Hamburg. Mitteilungen aus den Botanischen Instituten in Hamburg. Hamburgischen Wiss. Anst. Beiheft zum jahrb. **19**:182–183.
Records injury to chrysanthemums.

1913 Sorauer's Handbuch der pflanzenkrankheiten **3**:629–630.
Brief general account; recommends wood ashes.

Reuter, O. M.
1873* Capsiders synonymi. Notiser ür Sällskapets pro fauna et flora Fennica **14**:—.

1875* a Bidrag till Nordiska Capsiders synonymi. Notiser ür Sällskapets pro fauna et flora Fennica 14:1, with figures.

1875 b Capsinae ex America boreali in Museo Holmiensi asservatae, descriptae. Kongl. [Svenska] Vetensk. Akad. Ofversight Förhandl. 32:72.

Lists insect from South Carolina, Wisconsin, and New Jersey.

1875 c Hemiptera gymnocerata Scandinaviae et Fenniae, part 1 : 70–73. Description and synonymy.

1881 Analecta hemipterologica. Berliner ent. zeitsch. 25:176. Synonymical note.

1888* Revisio synonymica Heteropterorum palæarcticorum quae descripserunt auctores vetustiores, p. 269. Helsingfors.

1892–1893 Capsidae Chinensis et Thibetanae. Finska Vetensk. Soc. Öfversight Forhandl. 45:13.

Lists insect from Khalgan.

1895 Hemiptera gymnocerata Europae 5:98–101.

Description and synonymy.

1906 Capsidae in prov. Sz'tschwan Chinae a DD. G. Potanin et M. Beresowski collectae. Mus. Zool. Acad. Imp. Sci. St.-Petersbourg. Ann. 10:27, 38–39.

Synonymy and distribution.

1907 Capsidae mexicanae a Do. Bilimek collectae in museo i. r. Vindobonensi asservati. K. K. naturhist. Hofmuseums. [Wien] Ann. 22:169.

Brief mention.

1909 Characteristik und entwicklungsgeschichte der Hemipterenfauna (Heteroptera Auchenarrhynchia und Psyllidae) der palæarktischen Coniferen. Soc. Sci. Fenn. Act. 36:1:80.

Records the insect on *Pinus silvestris* and *Picea excelsa* in Europe.

Riley, C. V.

1870 a Missouri State Ent. Ann. rept. 2:113–115, fig. 83.

General account; records injuries to cabbage, potato, apple, pear, plum, quince, cherry; recommends jarring, tobacco water, quassia water, vinegar, cresylic soap, cabbage trap-crop.

1870 b Apple-tree borer; variations in the two striped Saperda. Amer. ent. and bot. 2:276.

Mention.

1870 c The tarnished plant-bug. Amer. ent. and bot. 2:291–293, fig. 182. Abstract of article in first reference, 1870 a.

Records injury to pear and apple trees in Missouri and to cucumbers in Illinois; experiments with cresylic soap and jarring, by Mr. Ayers.

1872 Insects of Missouri. Rept. 4:20.

Mentions possibility that *Lygus pratensis* feeds on potato-bug larvæ.

1875 Insects of Missouri. Ann. rept. 7:26.

Brief mention.

1885 U. S. Ent. Rept. **1884:**312–315, pl. IV, fig. 3–4.
General account.

1893 U. S. Bur. Ent. Bul. 31 o.s.: 18, 24.
Mentions insect as injurious to pear leaves and strawberries; recommends jarring, kerosene emulsion, pyrethrum.

Riley, C. V., and Howard, L. O.

1889 The tarnished plant-bug on pear and apple. Insect life **2:** 49–50.
Records injury to pear and apple buds, and recommends kerosene emulsion.

1890 Insects affecting salsify. Insect life **2:**255.
Reports insect feeding on salsify.

1891 a Diseases of chrysanthemums caused by insects. Insect life **3:**351.
Refers to article by J. G. Jack.

1891 b Some strawberry pests. Insect life **3:**364.
Refers to bulletin by H. Garman.

1894 Insects injurious to celery. Insect life **6:**211.
Refers to bulletin by G. C. Davis.

Ritzema Bos, J.

1905 Verslag over onderzoekingen, ge daan in-en over inlichtingen gegeven van wege bovengenoemd laboratorium in net jarr 1904. Tijdschrift over plantenziekten **11:**43–44.
Insert recorded as injuring chrysanthemums.

Rossi, P.

1790* Fauna Etrusca **2:**243.

1807 Same. Illiger ed. **2:**389–390 (246–247).
Brief description and note on synonymy.

Rudow, F.

1891 Einige missbildungen an pflanzen, hervorgebracht durch insekten. Zeitsch. pflanzenkr. **1:**292, pl. V, fig. 6.
Mentions injury to *Chaenopodium*, *Atriplex*, and *Beta*.

Sahlberg, R. F.

1848 Monographia Geocorisarum Fenniae, p. 110–111.
Description.

Sanborn, C. E.

1912 Oklahoma Agr. Exp. Sta. Bul. 100:22–23.
Brief account; recommends clean culture and a contact spray.

Sanderson, E. D.

1902 Insects injurious to staple crops, p. 263, fig. 151.
Brief note; recommends kerosene emulsion, kerosene and water, and wood ashes.

1912 Insect pests of farm, garden, and orchard, p. 404–406, fig. 293.
General account; recommends clean culture, kerosene emulsion, insect net.

Sanderson, E. D., and Jackson, C. F.
1912 Elementary entomology, p. 117–118, fig. 157.
Brief general account.

Saunders, E.
1875 Synopsis of British Hemiptera-Heteroptera. Ent. Soc. London. Trans. **1875**:276.
Description.

1892 The Hemiptera Heteroptera of the British Islands, p. 249, 252, 253, pl. XXII, fig. 10.
Description; key to the British species of *Lygus*.

Saunders, W.
1870 a Entomological gleanings. Can. ent. **2**:111–112.
Mentions injury to pear buds and suggests use of soft soap and dry lime.

1870 b Entomological gleanings. Can. ent. **2**:126.
Brief note.

1883 Insects injurious to fruits, p. 147–148, fig. 153.
General account; recommends clean culture and jarring.

Say, T.
1831 Descriptions of new species of heteropterous Hemiptera of North America. New Harmony, Indiana. Original pagination unknown.

1857 Same, reprinted. New York State Agr. Soc. Trans., 756–814.

1859 Same. Le Conte ed. **1**:310–371.
Original description of *Capsus oblineatus* on page 340.

Schilling, P. S.
1837 Uebersicht der arbeiten und veränderungen der Schlesischen Gesellschaft für vaterlandische Kultur im jahre 1836, p. 83.
Brief description.

Scholtz, H.
1847 Prodromus zu einer Rhynchoten-Fauna von Schlesien. Übersicht der arbeiten und veränderungen der Schlesischen Gesellschaft für vaterländische Kultur im jahre 1846, p. 126, 136.
Brief list of references and systematic note.

Schöyen, W. M.
1902* Offentl. Foranst. Landbr. Fremme. Aarsber. **1902**:2: 110–153, fig. 21.

1903 Beretning om skadeinsekter og plantesygdommer i land-og havebruket **1902**:13–14, one figure.

Records insect as occurring on cabbage; unsuccessful experiments with paris green, caustic potash, milk of lime, bordeaux mixture, and tobacco decoction.

1911 Beretning om skadeinsekter og plantesygdommer i land-og havebruket **1910**:5, one figure.

Mentions insect as feeding on barley, oats. wheat, and timothy.

1912 Beretning om skadeinsekter og plantesygdommer i land-og havebruket **1911**:28.

Mention.

Scopoli, J. A.

1763 Entomologia carniolica, p. 133.

Description.

Sempers, F. W.

1894 Injurious insects and the use of insecticides, p. 91–92.

Brief general account; records injury to strawberries; recommends pyrethrum and kerosene emulsion.

Sherman, M. E.

1910 Features of vineyard work in San Joaquin valley. California cultivator **35**:531, 551.

Contains a description of C. B. Driver's suction apparatus for catching grape leaf-hoppers.

Siebke, H.

1874 Enumeratio insectorum Norvegicorum **1**:11.

Lists insect from various localities in Norway.

Slingerland, M. V.

1895 a A bad fruit bug. Rural New-Yorker **54**:328.

Brief general account; refers to injury to peach nursery stock. Suggests jarring into kerosene, kerosene emulsion, pyrethrum, clean culture.

1895 b A trio of bugs. Rural New-Yorker **54**:505.

Recommends kerosene emulsion.

1896 a Report of the Committee on Entomology. West. New York Hort. Soc. Proc. **1896**:23.

Description of injury to peach nursery stock; suggests use of insect net.

1896 b How to fight the tarnished plant-bug. Rural New-Yorker **55**:99.

Suggests use of kerosene emulsion.

Smith, J. B.

1890 Insects of New Jersey. 1st ed., p. 426.

Lists insect.

1899 Same. 2d ed., p. 129.
Lists insect.

1900 New Jersey Agr. Exp. Sta. Rept. **1899**:427–428, fig. 2.
Description of injury to peach nursery stock attributed to a thrips.

1909 Insects of New Jersey. 3d ed., p. 164, fig. 69.
Records insect as injurious to garden crops.

Smith, R. I.

1906 Georgia State Bd. Ent. Bul. 20:166.
Records injury to pear and apple stock in nursery, and states that 15-per-cent kerosene emulsion was successful.

Sorauer, P.

1896 Blutenarmut bei chrysanthemum und georginen. Zeitsch. pflanzenkr. **6**:55.
Mention of injury to chrysanthemums and dahlias.

Stål, C.

1858 Beitrag zur Hemipteren-fauna Sibiriens und des Russischen Nord-Amerika. Stettiner ent. zeitg. **19**:186.
Records insect from Alaska and eastern Siberia.

Starnes, H. N.

1896 Georgia Agr. Exp. Sta. Bul. 32:448.
States that insect attacks strawberries; recommends pyrethrum.

Stedman, J. M.

1899 Missouri Agr. Exp. Sta. Bul. 47:77–87, fig. 1–3.
General account, mostly compiled; recommends the use of butterfly net, kerosene emulsion, pyrethrum, " Rose Leaf " insecticide.

Stewart, V. B.

1913 a Cornell Univ. Agr. Exp. Sta. Circ. No. 20:90, 91.
Lygus pratensis mentioned as disseminating fire blight on peach and apple nursery stock.

1913 b Cornell Univ. Agr. Exp. Sta. Bul. 329:340, 368.
Tarnished plant-bug mentioned as a probable disseminator of fire blight on nursery stock.

1913 c The importance of the tarnished plant-bug in the dissemination of fire blight in nursery stock. Phytopathology **3**:273–276, pl. XXIII.
Observations proving that *Lygus pratensis* is a carrier of fire blight in nursery stock.

Stinson, J. T.

1895 Arkansas Agr. Exp. Sta. Bul. 33:80–81.
Brief account of injury to strawberries; recommends pyrethrum.

Strachan, C.

1893 Why dahlias fail to bloom. Garden and forest **6**:448.
Mentions injury to dahlias in Massachusetts.

Strobl, G.

1900 Die Steirische Hemipteren. Naturw. Verein Steiermark. Mitt., jahrg. 1899, **36**:188–189.

Common in Steiermark to the high Alps; establishes a variety *fuscorubra*.

Summers, H. E.

1891 Tennessee Agr. Exp. Sta. Bul. **4**:3:90–91.

Quotes Comstock's account.

Swenk, M. H.

1913 Nebraska State Ent. Bul. 1:87.

Notes occurrence of insect on wheat.

(Anonymous)

1914 Tarnished plant-bug on dahlias. Rural New-Yorker **73**:620

Brief description of injury to dahlias; recommends 7-per-cent kerosene emulsion or tobacco extract to kill young nymphs, also clean culture.

Taschenberg, E. L.

1871 Entomologie fur gartner und gartenfreunde, p. 491–493.

General account; recommends jarring.

Taylor, E. P.

1908 Dimples in apples from oviposition of *Lygus pratensis* L. Journ. econ. ent. **1**:370–375, pl. 10–11.

Describes oviposition in apple.

1909 Missouri State Fruit Exp. Sta. Bul. 21:68–69, fig. 16–18.

Brief account, with figures of dimples in apples caused by egg-laying punctures.

Theobald, F. V.

1903 First report on economic zoology (British Museum, Natural History), p. 30–31.

Brief account; mentions insect as attacking chrysanthemums; recommends jarring and soft-soap washes, especially paraffin emulsion with an extra 3 pounds of soft soap to 100 gallons.

1905 South-Eastern Agr. Col. [Wye]. Rept. **1904–1905**:63–66, fig. 26.

General account; records injury in England to pear, apple, plum, and poppy; recommends jarring, tarred sacks, paraffin emulsion to which is added 3 pounds of soft soap in 100 gallons, clean culture.

Thomas, C.

1878 Insects injurious to the vegetable garden. Illinois State Hort. Soc. Trans. **1877**:175–176.

General account; mentions injury to cabbage; recommends clean culture, whitewashing fences, stirring soil, and ashes around bases of trees.

Thompson, C. G.

1871 Opuscula entomologica, p. 423–424.

Brief description [illegible]

Townsend, C. H. T.

1891 Hemiptera collected in southern Michigan. Ent. Soc. Washington. Proc. **2**:54.
Reports insect collected on cowslip flowers.

1892 Biologic notes on New Mexico insects. Can. ent. **24**:193.
Brief note; records occurrence of insect on alfalfa.

Troop, J.

1892 Some injurious insects of the year. Indiana Hort. Soc. Trans. **1891**:73.
Mentions insect as injuring celery.

Tullgren, Alb.

1911 Uppsatser i praktisk entomologi **21**:50.
Mentions insect as occurring on currant, potato, dahlia, turnip, and cabbage.

1913* Skadejur i Sverige år 1911. Uppsatser i praktisk entomologi.

Uhler, P. R.

1863 In Harris, T. W., Flint edition, p. 200. (See reference on page 466.)
Footnote, in which Uhler says Harris has wrongly used *Phytocoris lineolaris* for *P. linearis*.

1872 a A list of Hemiptera collected in eastern Colorado and northeastern New Mexico, by C. Thomas, during the expedition of 1869. U. S. Geol. Hayden Survey, Wyoming, etc. Prelim. rept., p. 471.
Lists insect as *Lygus diffusus* and *L. redimitus.*

1872 b Notices of the Hemiptera of the western territories of the United States, chiefly from the surveys of Dr. F. V. Hayden. U. S. Geol. Hayden Survey, Montana, etc. Prelim. rept., p. 413.
Lists insect.

1876 List of the Hemiptera of the region west of the Mississippi River, including those collected during the Hayden explorations of 1873. Hayden Geol. and Geog. Survey, Terr. 1. Bul. 5:ser. 2:318.
Lists insect.

1877 Report upon the insects collected by P. R. Uhler during the explorations of 1875, including monographs of the Cydnidae and Saldidae, and the Hemiptera collected by A. S. Packard, jr., M. D. Hayden Geol. and Geog. Survey, Terr. 3. Bul. 2:415.
Lists insect.

1878 a On the Hemiptera collected by Dr. Elliott Coues, U. S. A., in Dakota and Montana during 1873–1874. Hayden Geol. and Geog. Survey, Terr. 4. Bul. 2:506.

1878 b Notices of the Hemiptera Heteroptera in the collection of the late T. W. Harris, M. D. Boston Soc. Nat. Hist. Proc. **19**:407.
Note.

1886 Check-list of the Hemiptera Heteroptera of North America, p. 18.
Lists insect.

Uzel, H.

1910* Bericht über krankheiten und feinde der zuckerrübe in Böhmen und der mit derselben abwechselnd kultivierten pflanzen im jahre 1908. Zeitsch. zuckerind. Böhmen **34**:349. Abs. in Centbl. bakt. 2:**27**:276 [1910]; **30**:581 [1911].
Records insect as abundant on beet leaves.

1911* Krankheiten und feinde der zuckerrube in Böhmen und anderer kultivierter pflanzen im jahre 1909. Zeitsch. zuckerind. Bohmen **35**:563. Abs. in Centbl. bakt. 2:**32**:302 [1912].
Mentions insect as an enemy of sugar beets.

1913 Ueber die insekten, welche die bluten der zucker- und futterrübe besuchen. Zeitsch. zuckerind. Bohmen **37**:194.
Mentions the insect as an enemy of sugar beets in North America.

Van Duzee, E. P.

1887 Partial list of Capsidae taken at Buffalo, New York. Can. ent. **19**:71.
Lists insect.

1889 a Hemiptera from Muskoka Lake district. Can. ent. **21**:3.
Lists insect.

1889 b On a new species of Pediopsis. Psyche **5**:240–241.
Brief note.

1894 A list of the Hemiptera of Buffalo and vicinity. Buffalo Soc. Nat. Sci. Bul. 5:177.
Lists insect.

1905 List of Hemiptera taken in the Adirondack Mountains. New York State Mus. Bul. 97:551.
Lists insect.

Walckenaer, C. A.

1802 Faune parisienne **2**:347.
Brief description.

Walker, F.

1873* Catalogue of the specimens of Hemiptera Heteroptera in the collection of the British Museum **6**:82, 91.

Walsh, B. D.

1860 Entomological notes. Prairie farmer **21**:308.
Mentions injury to apple blossoms and pear buds.

1863 Insects injurious to fruit trees. Prairie farmer **24**:276.
Account of injury to pear buds; recommends hand picking.

1866 Answers to correspondents. Pract. ent. **1**:77–78.
Mentions insect as occurring in Wisconsin.

Walsh, B. D., and Riley, C. V.
1869 Answers to correspondence. Amer. ent. **1**:227, 228.
Mention.

Washburn, F. L.
1902 Minnesota Agr. Exp. Sta. Bul. 77:62–63, fig. 53, 54.
Records injury to currants, also attacks on plum and flowering shrubs; reports that insect reduced currant crop to one third; recommends brushing onto sheets.

1903 Minnesota Agr. Exp. Sta. Bul. 84:85, fig. 72.
Recommends clean culture and possibly a kerosene spray.

1904 Minnesota Agr. Exp. Sta. Bul. 88:53, 60, 78, fig. 36.
Mentions insect as pest of berries, currants, and strawberries; recommends clean culture.

Wassiliew and Miram
1908* Centralblatt fur der zuckerindustrie **16**:704. Abs. in Centbl. bakt. 2:**23**:175.
Mentions insect as injurious to beets in Russia.

Webster, F. M.
1886 Insects affecting fall wheat. In Riley, C. V., U. S. Ent., Rept. **1885**:317.
Records injury to wheat.

1887 a Insects of the year. Indiana State Hort. Soc. Trans. **1886**:115–116.
General account; mentions injury to rosebuds; suggests pyrethrum mixed with water, and kerosene emulsion.

1887 b A record of some experiments relating to the effect of the puncture of some hemipterous insects upon shrubs, fruits, and grains, 1886. U. S. Bur. Ent. Bul. 13 o. s.:54–58.
Experiments on the effect of feeding on strawberries and other plants.

1888 Two alien pests of the greenhouse. Insect life **1**:198.
Records injury to chrysanthemums in a greenhouse in Indiana, and states that the bugs were destroyed by fumigating with tobacco smoke.

1890 a Insects affecting salsify. Insect life **2**:255.
Records injury to salsify.

1890 b Notes on garden insects. Insect life **3**:150.
Reports insect devoured by a spider.

1893 Ohio Agr. Exp. Sta. Bul. 45:213–216, fig. 36–37.
General account quoted from Forbes' thirteenth report; recommends kerosene emulsion.

1899 The new peach mite in Ohio. Ent. news **10:**14.
Records injury to peach nursery stock in Ohio.

Webster, F. M., and Mally, C. W.

1897 Insects of the year in Ohio. U. S. Bur. Ent. Bul. 9:42.
Records injury to asters.

1899 Insects of the year in Ohio. U. S. Bur. Ent. Bul. 20:72.
Records injury to peach nursery stock.

Weed, C. M.

1891 a The tarnished plant-bug. Columbus Hort. Soc. Ann. rept. **1890:**166.
Brief general account; recommends pyrethrum and kerosene emulsion, and suggests use of insect net.

1891 b Insects and insecticides. 1st ed., p. 93–94, fig. 40.

1901 New Hampshire Agr. Exp. Sta. Bul. 81:14.
Records insect as destructive to sweet peas; recommends brushing into pans of kerosene.

1903 Insects and insecticides. 2d ed., p. 143–144, fig. 71.
Brief general account; recommends pyrethrum and kerosene emulsion, and suggests use of insect net.

Whiteside, F.

1906 Montana State Hort. Bd. Bienn. rept. 4 for 1905–1906:40–41.
Brief general account; recommends jarring.

Wier, D. B.

1872 The tarnished plant-bug. Prairie farmer **33:**26.
Original observations; records injury to pear, apple, plum, and mountain ash; reports experiments with trap crop; suggests clean culture and fall plowing.

1875 The fruit grower and the bugs. Illinois State Hort. Soc. Trans. **1874** n. s. **8:**29–33.
General account; reports injury to pear and apple; recommends hand picking in spring, and deep plowing.

Wilkinson, A. E.

1913 Modern strawberry growing, p. 66–67.
Brief account; insect mentioned as injurious to young strawberries; recommends pyrethrum and kerosene emulsion.

Wirtner, M.

1904 A preliminary list of the Hemiptera of western Pennsylvania. Carnegie Mus. Ann. **3:**1:196.
Lists insect.

Witte, P.

1893 Prakt. rathgeber obst- u. gartenbau. Anzeigenteil **8**:56.

Mentions injury to chrysanthemums in Germany; varieties injured, Fair Maid of Guernsey, Mount Mascal, Stanstead White (late varieties); Fanny Boucharlat immune; recommends petroleum and water, 1–500, and says that plants grown in shade are benefited.

Woodworth, C. W.

1889 Arkansas Agr. Exp. Sta. Bul. 10:7–18, fig. 1–5.

General account of injuries, mostly compiled; describes and figures the eggs dissected from female; recommends jarring in flower garden and nursery, pyrethrum, and kerosene emulsion.

1890 a Same. Arkansas Agr. Exp. Sta. Ann. rept. **2** for 1889:147–158.

1890* b Southern cultivator and Dixie farmer, p. 254–265, 5 figures.

Zetterstedt, J. W.

1828 Fauna insectorum lapponica, p. 273, 289.

1840 Insecta lapponica descripta, p. 273.

Description.

A LIST OF THE CAPSIDAE OF NORTH AMERICA THE EARLY STAGES OF WHICH ARE BEST KNOWN

Adelphocoris rapidus Say.
Lugger. Minnesota Agr. Exp. Sta. Bul. 69. 1900.
Forbes. Illinois Agr. Exp. Sta. Bul. 60:440–441. 1900.
Forbes. Illinois State Ent. Rept. **21**:92. 1900.
Sanderson. U. S. Bur. Ent. Bul. 57:44–46. 1906.

Dicyphus minimus Uhler.
Quaintance. Florida Agr. Exp. Sta. Bul. 48:167–175. 1898.

Heterocordylus malinus Reuter.
Crosby. Cornell Univ. Agr. Exp. Sta. Bul. 291. 1911.

Hyaliodes vitripennis Say.
Summers. Tennessee Agr. Exp. Sta. Bul. 1:4:32–33. 1891.

Lygidea mendax Reuter.
Crosby. Cornell Univ. Agr. Exp. Sta. Bul. 291. 1911.

Lygus invitus Say.
Parrott and Hodgkiss. New York (Geneva) Agr. Exp. Sta. Bul. 368. 1913.
Parrott and Hodgkiss. New York (Geneva) Agr. Exp. Sta. Circ. 21. 1913.

Paracalocoris colon Say.
Parrott and Hodgkiss. New York (Geneva) Agr. Exp. Sta. Bul. 368. 1913.

Paracalocoris scrupeus Say.
Parrott and Hodgkiss. New York (Geneva) Agr. Exp. Sta. Bul. 368. 1913.

Pœcilocapsus lineatus Fabricius.
Slingerland. Cornell Univ. Agr. Exp. Sta. Bul. 58. 1893.

Stenotus binotatus Fabricius.
Howard. Insect life **5**:90–92. 1892.

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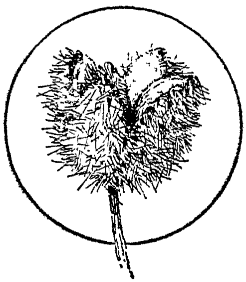
ENDOTHIA CANKER OF CHESTNUT



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CANKER ON TRUNK OF CASTANEA DENTATA CAUSED BY THE FUNGUS ENDOTHIA PARASITICA. YELLOW TENDRILS OF PYCNOSPORES SHOWN AROUND MARGIN

CONTENTS

ENDOTHIA CANKER OF CHESTNUT

P. J. Anderson and W. H. Rankin [1]

(*Received for publication March 27, 1914*)

HOSTS

The Endothia canker was first discovered by Merkel (1906), on the American chestnut (*Castanea dentata*), in the New York Zoological Park during the summer of 1904. Metcalf (1908 a) states: "Observations made by the writer during the past year indicate that all varieties and species of the genus Castanea are subject to the disease except the Japanese varieties (*Castanea crenata* Sieb. and Zucc)." In the same year Metcalf (1908 b) states that the Japanese varieties are in general resistant, and Murrill (1908 a: 27) reports having found the canker on a Japanese chestnut and on the chinquapin (*Castanea pumila*) in the New York Botanical Gardens. Pantanelli (1911), Metcalf (1912 b: 76), and Morris (Clinton 1911: 725) give evidence that varieties of the European chestnut (*Castanea sativa*) are also subject to this disease. Morris (Clinton 1913: 376) gives his observations on orchard varieties as follows: Corean, Chinese, and northern Japanese varieties were not attacked, although they had grown for five years alongside diseased trees, while southern Japanese varieties were attacked; but the Corean, Chinese, and northern Japanese varieties were attacked after having been grafted on American stocks. A small number of the eastern and the western chinquapins were unaffected except for one branch of a single tree. Many points that are essential for determining the real value of these observations as establishing the immunity or the susceptibility of these varieties are unfortunately not given. Fairchild (1913) reports having found the disease in northern China on a species of Castanea, probably *C. mollissima*.

Van Fleet (1914) records many observations concerning the spread of the canker in the breeding-plots at Washington, D. C., where he has been breeding chestnuts experimentally since 1894. Nearly all the trees having *C. americana* in any combination have disappeared. Recently Van Fleet has worked with selections made from self- and chance-pollinated individuals of the chinquapin and Asiatic types. He has obtained many precocious hybrids from these crosses. He reports his observations on the resistance to the canker shown by these hybrids as follows:

"Seedlings of Paragon chestnut, the best variety of the European type, pollinated with our native species, attained an average height of

[1] Names of authors arranged alphabetically.

twenty-five feet and were bearing excellent nuts when attacked in 1910, but all have succumbed. The crosses of Asiatic and native, fewer in number, showed greater resistance but all have been seriously affected. The chinquapin-European hybrids are readily affected but have great recuperative powers, bearing nuts the second year on suckers springing from the bases of diseased stems. Chinquapin-native crosses with the exception of the Rush chinquapin — a probable natural hybrid found wild in Pennsylvania — appear very susceptible and do not as readily recover. The wild chinquapin itself appears measurably resistant, several individuals, including two Rush chinquapins, thriving for years with no signs of disease though constantly surrounded by infection.

"The Asiatic chestnuts, and the chinquapin-Asiatic hybrids, are plainly highly resistant. Few have shown any appearance of infection and when noticeable the injury is quite local in character. Second generation seedlings of chinquapin-crenata crosses show no disease at all though always exposed to infection."

Morris (1914) reports that five trees of the species *C. mollissima* have not been affected, although American trees have died all around them. Specimens of *C. alnifolia* also have remained free from the disease.

In brief, it may be said that there is no species of Castanea which is wholly immune. Some varieties show marked resistance, especially Asiatic varieties, and Metcalf (1914) claims apparent immunity for certain strains. On the other hand, no species outside the genus Castanea is known to be seriously affected.

The species of Castanea are confined to the northern hemisphere and are widely distributed through their range. Schneider [2] states that there are five species which are very closely related one to the other, in part probably representing only geographical varieties. The following species are recognized: *C. crenata*, of Japan and Central China; *C. sativa*, of southern Europe and northern Africa, and eastward to Persia; *C. dentata* and *C. pumila*, of eastern and southern United States. A species *C. mollissima*, of which little is known, has been described from China.

Many varieties from Europe, Japan, and China have been introduced into the United States for orchard culture. Taylor [3] states that the European chestnut was introduced into this country in 1803 and the Japanese chestnut in 1876. Corsa,[4] speaking of the European and the Japanese species, states: "Both species can be grown in portions of this country, either as seedlings or as grafted trees on American stock. . . The majority of imported trees and seedlings raised in this country from

[2] Schneider, C. K. Handbuch der laubholzkunde 1: 156. 1906.
[3] Taylor, W. A. Bailey's Encyclopedia of American horticulture 1: 294.
[4] Corsa, W. P. Nut culture in the United States. U. S. Agr. Dept., Pomol. Div. 1896. (Unnumbered bulletin.)

imported nuts are injured or killed entirely by our severe winters. It is doubtful whether five per cent of the imported European chestnuts live long enough to come into bearing, but stocks raised from seed of the few exceptional hardy trees which do flourish here are generally hardy, and in this way a strain of European chestnuts has been secured that is well adapted to the climate of the Eastern States. . . . Trees from nuts imported from France and Spain have been fruiting for at least a half century near Philadelphia, Pennsylvania, and Wilmington, Delaware." These cultivated varieties are now being grown throughout the eastern and southern States, although the greater part of the chestnut-growing industry is confined to the States of Delaware, Maryland, Pennsylvania, New Jersey, New York, and Connecticut.

There are two native American species of Castanea, *C. dentata* and *C. pumila*. Sargent [5] gives the distribution of the forest species (*C. dentata*) as from " southern Maine to the valley of the Winooski River, Vermont, and southern Ontario, along the southern shores of Lake Ontario to southern Michigan, southward to Delaware and southeastern Indiana, and along the Alleghany Mountains to central Alabama and Mississippi, and to central Kentucky and Tennessee . . . . attaining its greatest size in western North Carolina and eastern Tennessee " (Fig. 77, page 542). *C. pumila*, as described by Sargent,[5] is found from southern Pennsylvania to northern Florida and west to Arkansas and Texas, is usually shrubby in the region east of the Allegheny Mountains and arborescent west of the Mississippi River, and is most abundant and reaches its largest size in southern Arkansas and eastern Texas.

ECONOMIC VALUE OF CHESTNUT

From an economic standpoint the American chestnut is by far the most important species. It is one of the main forest trees of New York, Connecticut, Pennsylvania, and the Allegheny Mountain region southward to Alabama. The cut of chestnut comprised about seven per cent of the total amount of hardwood timber cut in the United States in 1910. In 1907 the United States Bureau of the Census [6] reports: " Chestnut is a wood whose use for lumber has increased remarkably within the last few years. The total cut in 1907 was over three times as large and its total value over four and one half times as great as in 1900 . . . having a value of $11,130,547 . . . . nearly one half of the total cut was reported by Pennsylvania, West Virginia, and Tennessee. . . . In addition to being largely used for lumber, much chestnut is also cut into posts, poles, rails, and cross-ties, and used in the manufacture of

[5] Sargent, C. S. Manual of the trees of North America, pp. 220–222. 1905.
[6] The lumber cut of the United States, 1907. U. S. Census Bureau. Forest Products, No. 2 : 1–53. 1908.

tanning extract." For 1907 the value of the chestnut used in the latter products amounted to $1,619,785 for poles, about $3,500,000 for ties, $2,560,007 for tanning extract, and $377,880 for slack-cooperage. The total value for all chestnut used in the products reported amounted to $19,188,219 in 1907. The later reports show but little variation from these figures for the yearly consumption. Unfortunately value computations are omitted in the reports for 1910 and 1911. For 1909 the total value of the chestnut cut, according to the reports, amounted to $19,098,581.

Besides its commercial value the chestnut has been utilized in its natural range as a much-favored ornamental. Many large estates in New York, Pennsylvania, New Jersey, and Connecticut valued their chestnut trees very highly. As an orchard tree the varieties of the American and the foreign species are of relatively less economic importance. The chinquapin, except as a variety for nut production, is of little commercial value.

The chestnut tree is our most important source of tanning extract. We know of no rapidly growing species that could be economically substituted in case of its extinction. The result of this would inevitably be a material increase in the cost of tanning leather.

SOIL REQUIREMENTS

Concerning the soil requirements of the chestnut, Zon [7] states:

" Chestnut is not very exacting in its demands upon the nutritive substances of the soil, but requires that it be deep, fresh, loose, and moderately fertile. The development of chestnut seems to depend more on the situation and the physical conditions of the soil than on its chemical composition. A moderate amount of clay, though not enough to interfere with the looseness of the soil, together with some potassium and lime, suits the species best. . . .

" Chestnut is a deep-rooted species, which derives its nutrition from the lower layers of earth — a fact explaining its vigorous growth on exposures with poor surface soil."

NATURAL REPRODUCTION

Quoting further from Zon: " The conditions for the reproduction of chestnut from seed are very unfavorable. The presence of man, who has made a business of gathering and selling chestnuts, of hogs, which seek them greedily, and of coppice chestnut and other hardwoods, under whose dense shade the chestnut seedlings must come up, renders reproduction from seed almost impossible."

[7] Zon, Raphael. Chestnut in southern Maryland. U. S. Forestry Bur. Bul. 53 : 1–31. 1904.

The chestnut is noted for its ability to sprout from the collar after the tree is cut, forming a dense growth of coppice. Practically all the second and successive growths of chestnut in the Eastern States have come about in this way. This coppicing method of reproduction is followed in forestry practice to great advantage. The influence of different factors on the thriftiness of coppice growth are discussed by Zon.[8] Many persons have contended that this practice has devitalized the chestnut, making it more susceptible to diseases; however, as Metcalf (1912 b:81–82) says, there seems to be no substantiating evidence for such an assertion. The marked abundance of dead branches on slow-growing chestnuts has been taken as a sign of their debility.

The opinion that the chestnut has not always been thrifty throughout its range is based on observations of various writers. Clinton (1913: 407–408) discusses this subject, quoting extensively from many sources. He states: "It is well known that in times past the chestnut trees in this country have suffered severely in certain districts, particularly in the South, in some cases being practically exterminated, so that their range is now considerably lessened from what it was originally. Strangely enough, no one has surely accounted for any of these devastations. Personally we believe that this tree is extremely susceptible to changes in the natural environment, and that such changes, with water playing an important part, have been the chief factors back of the gradual decline of this important forest tree. Other factors, such as forest fires, deterioration through repeated cuttings, insect and fungus attacks, are contributing causes varying in different localities."

THE DISEASE

NAME

The present epiphytotic disease of the chestnut has become known by several common names. Metcalf (1908 a) applied the name "bark disease," and since that time this name, as well as the name "blight," has been used by most writers. Murrill (1908 b) used the name "canker," but unfortunately this name has found preference with but few writers.

There are arbitrary rules, at least, for the naming of types of diseases. The term "canker" has come to mean, both to the pathologist and to the layman in this country, a disease which causes the death of definite areas of the bark of the limbs or the trunks of trees. The various apple-tree cankers are well known. There is no conflict in meaning, therefore, between the names "bark disease" and "canker," for they are synonymous; but, since we already have in common use the name "canker,"

[8] Zon, Raphael. Chestnut in southern Maryland. U. S. Forestry Bur. Bul. 53: 1–31. 1904.

there is no logical reason why we should not use it for this disease. Pantanelli (1911) says this name does not seem very exact, as very different alterations of a tree are understood by the word "canker." In a later article, however, Pantanelli (1912:869) used the name "canker."

It is true that European writers attach to the name "canker" the additional significance of a callus formation around the diseased area. Thus they retain the original Greek neaning of the root of the word, which meant an excrescence on the limbs of trees.

The name "blight" has been more generally applied to rapidly spreading and destructive diseases of herbaceous plants or the herbaceous parts of woody plants. As the term "blight" in the case of this disease signifies only a symptom of the disease, not the lesion, it is evidently not so appropriate as either of the other two names. The authors of this bulletin prefer to use the name "canker," and in order that the name may be entirely specific it should be called the Endothia canker of the chestnut.

HISTORY

In the first published account of the Endothia canker, Merkel (1906:97) says: "This disease was first noticed in the New York Zoological Park, in a few scattered cases which occurred during the summer of 1904." In a letter to the writers Mr. Merkel adds: "No indication of the chestnut-tree disease was noticed by me previous to the year 1904. In 1904, however, toward the latter part of the season, I noticed that certain very old chestnut trees were suffering in certain portions of their tops from some trouble or other, but no investigation was made of the cause. . . . Early during the following year, in fact on June 17, I became thoroughly alarmed and sent to the Bureau of Forestry a specimen of the disease on a young tree and a letter asking for information."

Metcalf and Collins (1909:45) state: "Even at that time [referring to the discovery of Merkel in 1904] it is certain that it had spread over Nassau county and Greater New York, and had found lodgment in the adjacent counties of Connecticut and New Jersey. No earlier observation than this [1904 by Merkel] is recorded, but it is evident that the disease, which would of necessity have made slow advance at first, must have been in this general locality for a number of years in order to have gained such a foothold by 1904. Conspicuous as it is, it is strange that the fungus causing this disease was not observed or collected by any mycologist until May, 1905, when specimens were received from New Jersey by Mrs. F. W. Patterson, the Mycologist of the Bureau of Plant Industry."

This was the starting-point of the numerous investigations conducted by a large number of workers. Metcalf and Collins (1911:5) state:

"There is reliable evidence, however, that it was present on Long Island at least as early as 1893." This statement was based entirely on the recollections of certain observant nurserymen.

ORIGIN OF THE EPIPHYTOTIC

In his first publication Murrill (1906 a: 153) advances the theory that "it is possible that the conspicuous ravages of the disease about New York City are largely due to the severe and prolonged winter of 1903–04, during which many trees of various kinds were killed or injured." Metcalf (1908 a: 56) believed it possible that the Japanese chestnut had been the means of introducing a new fungous disease to this country. Clinton (1909: 887), after discussing observations that he had made, states: "From the preceding account one can readily see that the writer believes that the fungus alone is not entirely responsible for the havoc. . . . . Winter injury in 1903–04, aggravated by the droughts, especially that of 1907, we believe to have been important factors in handicapping the trees so that the way was opened for further serious injury by the fungus."

From these statements and the evidence cited for upholding this view, it is seen that Clinton did not believe a new and dangerous pathogen was being dealt with; but, as he states later, he believed that a native obscure fungous disease had suddenly sprung into prominence, due more to the condition of the host than to the potentialities of the organism. These two quite divergent opinions were each based on circumstantial evidence which will be more fully treated under etiology and ecologic relations. As a solution of the problem pathologists welcomed the finding of the disease in China in 1913, for this furnished a satisfactory basis for explaining many factors concerning the epiphytotic.

It therefore seems certain that Metcalf's assumption as to the origin of the outbreak has been proved correct. The opposing views of others, which no longer have any significance in accounting for the origin of the disease, are nevertheless important points to be considered under the influence of ecologic factors on the fungus, the susceptibility of the host, and the possible augmentation of the epiphytotic.

SPREAD IN THE UNITED STATES

The rapidity of spread has been phenomenal, and the completeness of destruction is without parallel in the annals of plant pathology. Merkel (1906) wrote in November, 1905: "Since that time [1904], however, it has spread to such an extent that to-day it is no exaggeration to say that ninety-eight per cent of all the chestnut trees in the parks of this borough [Bronx] are infected." Metcalf and Collins (1909: 45) state that specimens were received from New Jersey in May, 1905. Murrill (1906 a:

143) states in June, 1906: "The same disease has been found to exist among the chestnuts of New Jersey, Maryland, and Virginia." As to the authenticity of the records in Maryland and Virginia at this date the writers of this bulletin are in doubt.

Murrill (1906 b.203, 207) states in September, 1906: "I now know of very few chestnut trees in this portion [Bronx] of the city that appear to be worth trying to save and I do not consider any immune"; and further: "Mr. Levison reports all the chestnut trees of Forest Park, Brooklyn, to be either dead or dying, and many in Prospect Park to be seriously affected. Wherever he has found the chestnut tree in Brooklyn, he has found the disease."

Metcalf (1908 a: 55) states in February, 1908: "The bark disease.... is now reported from Connecticut, Massachusetts, Vermont, New York as far north as Poughkeepsie, New Jersey, Pennsylvania, and possibly Delaware." In the same month Murrill (1908 a: 26) reports approximately the same distribution, and adds Maryland to the list. Clinton (1908: 345) reports that the disease has become common in the neighborhood of Stamford, Connecticut. Hodson (1908: 4–5), after giving more nearly exactly the location of diseased areas in each State, sums up the situation thus: "The range at present, then, includes eight states, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and Massachusetts." Mickleborough (1909) reports the presence of the disease in six counties in eastern Pennsylvania, and Clinton (1909: 881–885; 1911: 716–717; 1913: 371–372) gives the data regarding the spread of the disease in Connecticut.

Metcalf and Collins (1909: 46) present a map showing the distribution at that time in so far as it was known. By this map it was shown that the disease was found in Rhode Island and southern Connecticut, in New York, New Jersey, and Delaware, and in eastern Pennsylvania, Maryland, and Virginia. They add: "It can be quite confidently stated that the bark disease does not yet occur south of Virginia and at only a few points in that State." Metcalf (1910) states: "At the present time it has spread from Saratoga county, New York, and Suffolk county, Massachusetts, on the north and east, to Bedford county, Virginia, on the south, and Greenbriar and Preston counties, West Virginia, and Westmoreland county, Pennsylvania, on the west."

Metcalf and Collins (1912) publish a detailed map which shows the results of more nearly accurate surveys of the territory along the border line of the spread of the disease. No new States were added to the distribution as already given above, although spot infections were found in many places in Massachusetts, western Pennsylvania, Maryland, and northern Virginia.

The latest published information is given by Metcalf (1914: 8), who reports: "The disease is now generally distributed in native chestnuts from Merrimack county, New Hampshire, and Warren county, New York, on the north, to Albemarle county, Virginia, on the south. In New York the western border of distribution is sharply delimited by an area without chestnut trees—a natural 'immune zone'—which extends southward along the eastern borders of Fulton, Montgomery, and Schoharie counties nearly to the Pennsylvania line in Delaware county. Consequently, in New York the range of the disease is at present practically limited to the valley of the Hudson. In Pennsylvania the western limit of general infection is roughly along a curved line extending from the northwest corner of Susquehanna county to the eastern border of Clearfield county and on to the southwest corner of Fulton county. West of this line the advance infections were cut out by the Pennsylvania Chestnut Tree Blight Commission. The disease has not yet been found in Ohio or Indiana. In general it appears to spread northeastward and southwestward, following the direction of the ridges of the Appalachians, much more rapidly than westward, across the ridges and valleys.

"Scattering infections occur outside of this area. Of these, the outposts are two infections on planted chestnuts in Franklin and Androscoggin counties, Maine, and one infection in a nursery in North Carolina. There is reason to suppose that the North Carolina infection, and an orchard infection in British Columbia, owe their origin to trees imported directly from the Orient."

The data for the map, Fig. 77, were furnished by Dr. Haven Metcalf, and represent the distribution known to him on March 1, 1914.

One might infer from the above that the disease has been spreading in ever-widening circles from the region about New York City. However, Clinton (1913:374) remarks: "This apparent wave of progress, however, is in part due to a corresponding wave of interest on the part of the people to locate a disease so generally discussed." He, as well as many others, believes that the disease has not started from a single center, but that other affected localities, such as those in Warren county, New York, Bedford county, Virgina, and Lancaster and York counties, Pennsylvania, are nearly as old as that about New York City. Even though the disease was imported from the Orient, as now seems certain to have been the case, it is reasonable to suppose that there were centers of infection started at distant places by the shipment of nursery stock. None of these outlying centers, however, have developed areas of total destruction such as that around New York City; so that it is still reasonable to suppose, from the evidence at hand, that this was the original center and that all other centers were early spot infections originating from it or from later direct importations.

DISTRIBUTION IN NEW YORK STATE

One of the writers of this bulletin (Rankin, 1914) reports the results of the surveys conducted in New York State as follows:

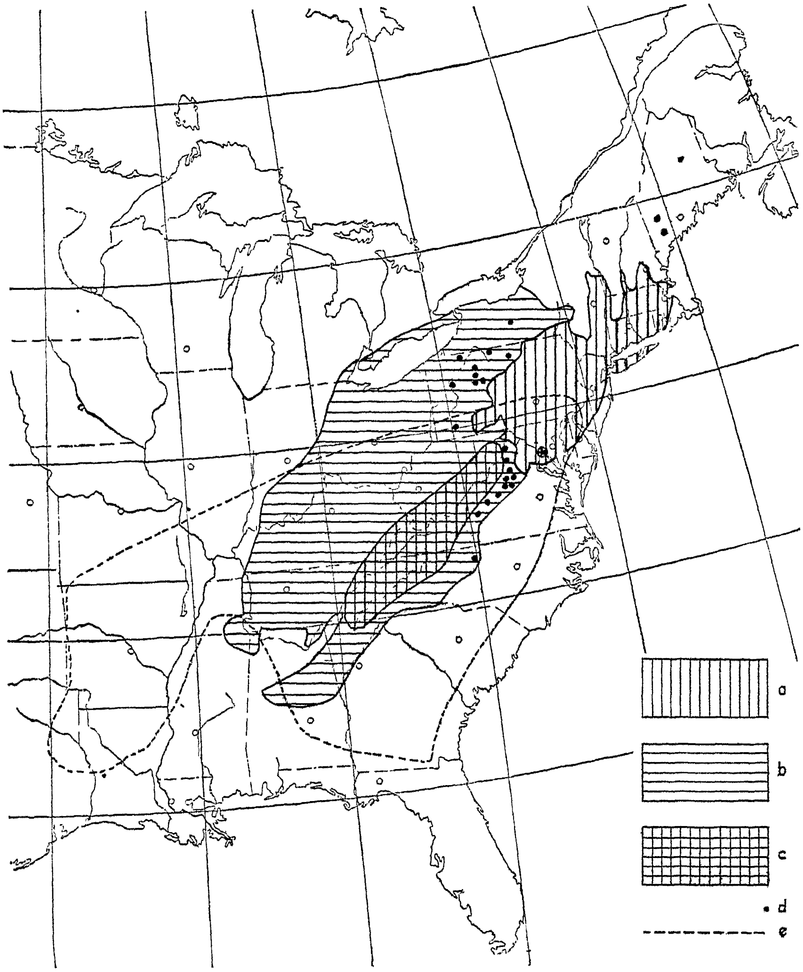

FIG. 77.— *Map showing present distribution of the chestnut canker in the United States. Furnished by Dr. Haven Metcalf*

a. Area over which the chestnut canker is abundantly present

b, Area of natural range of Castanea dentata as yet unaffected except for a few spot infections

c, Area of heaviest stands of chestnut

d, Location of known spot infections

e, Limit of natural range of the chinquapin, Castanea pumila

" At the outset of this investigation [May, 1911] the information available concerning the distribution of the disease attributed the northern limit of its range to southern Dutchess and central Orange counties.

It was known to be generally established in the western part of Long Island, Staten Island, and the counties of New York, Westchester, and Rockland. It was also expected that Orange county had been invaded to some extent."

Range of the chestnut in New York State

Reference to the accompanying map (Fig. 78) shows that the chestnut region of the State lies in two almost separated areas — the Hudson Valley, and the central and western parts of the State — and the two areas are connected by a narrow band of chestnut skirting the Delaware

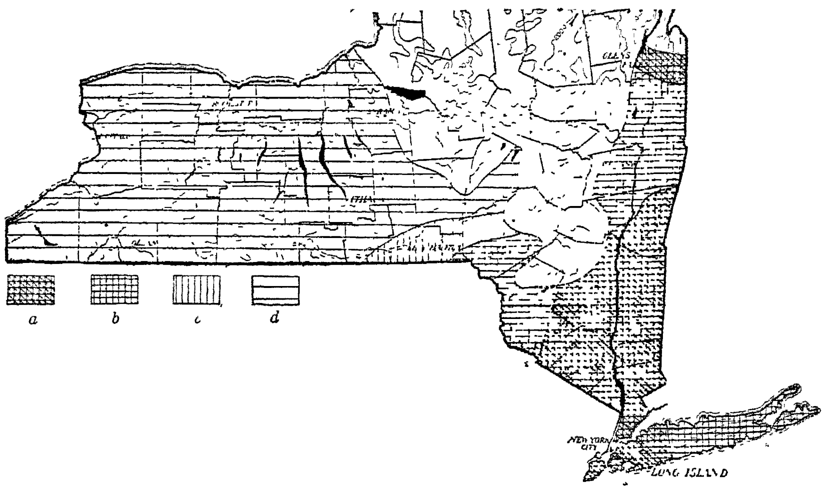

FIG. 78.— *Map showing distribution of the chestnut canker in New York State*
a, Canker abundantly present in 1911
b, Spot infections numerous in 1911
c, Spot infections numerous in 1913
d, Area containing more or less chestnut that is healthy

River in Sullivan and Delaware counties. There is no chestnut to be found in the Adirondack Mountains, and but little in the Catskill Mountains and the Highlands in Ulster, Sullivan, and Delaware counties. The extreme northeastern corner of the State contains but a few scattering chestnut trees.

Conditions in 1911

The accompanying map (Fig. 78) shows the results of the survey in fixing the limits of spread of the disease at that time. East of the Hudson River the disease was found abundantly as far north as Albany. The chestnut is most abundant along the state line between New York and Connecticut and Massachusetts, in the range of mountains making up

the Berkshires. Along the Hudson River the chestnut is plentiful, but not so abundant as in the hills. It was along the state line, in these heavy stands of chestnut, that the disease had made the greatest ravages. It was present, however, in every locality where there was any quantity of chestnut. Practically every town east of the Hudson River is represented in the list of those in which the disease was found. In those towns in this region from which the disease was not reported, the stand of chestnut was slight. In the central part of Rensselaer county there is little chestnut, and especially is this true of the part near the Hudson River. Along the state line separating New York from Massachusetts and Vermont, in the continuation of the Berkshires northward, there is considerable chestnut, but no disease was found there.

The natural northern limit of the chestnut, as is seen by the map, is in the towns of Fort Ann and Granville, in Washington county. The disease was found very abundant throughout Washington county. Many lumbermen were cutting chestnut as rapidly as possible in the towns of Hartford, Argyle, and Hebron, in order to keep ahead of the disease.

West of the Hudson River the disease had not advanced so far north. Practically the entire stand of chestnut in Orange county and in southern Ulster county was diseased. In the Catskill Mountains proper there is much chestnut in the valleys opening into the Hudson River Valley. In the southernmost of these valleys the disease had spread as far as chestnut is to be found, but in the Esopus Valley and in the valleys north of it the disease had spread for only a little distance. In Albany county the chestnut is scattering, except in the Helderberg Mountains, and it is very scarce in the western part of the county. A complete survey of Albany county was not made, owing to the unimportance of this information; however, the disease was found general in the southern part of the county along the Hudson River.

The connecting link between the chestnut region of the Hudson River Valley and that of the central and western part of the State is the strip in Sullivan county along the Delaware River. Chestnut is abundant here for fifteen to twenty miles away from the river. Many isolated spot infections were found here. The general spread extended about as far up the Delaware River as Port Jervis. A few spot infections were found in southern Delaware county along the Delaware and Susquehanna rivers. One spot infection was found at Masonville, Delaware county, and was destroyed. No infections were known west of this region in 1911. A special investigation of the cause of the dying of the chestnut near Cooperstown was made, but it was found not to be due to the canker disease.

Conditions in 1913

A hasty resurvey of the territory bordering on the line of advance determined in 1911 was made in September, 1913, for Doctor Metcalf. The area just west of the chestnut-free belt was covered, and the line as drawn on the map (Fig. 78) was fixed as representing approximately the limit of spot infections at that time. The strip along the Delaware River where isolated spots were found in 1911, was found at this time to be abundantly affected. The disease seems not to be spreading so rapidly north as west, and no infections were found in Otsego county just west of the chestnut-free belt in the Catskills. The width of this belt varies from thirty to forty miles, and it is interesting to note that apparently this distance has furnished a natural barrier which has so far impeded the dissemination of the fungus westward from the diseased areas along the west bank of the Hudson River.

ECONOMIC IMPORTANCE

Several writers have attempted to estimate in pecuniary value the losses due to the Endothia canker. The disease not only kills the merchantable trees on which a pecuniary value can be placed, but also destroys the young growth which would have been cut in the future, the value of which cannot be determined accurately. Aside from this, the æsthetic loss from the destruction of thousands of shade and ornamental trees cannot be computed in dollars.

Great as the damage has been, it seems that estimates are worth but little because of the lack of accurate data. Clinton (1913:379) tersely sums up the situation: "Just how this loss is estimated is not made very clear. To the writer it seems to be largely guess work. However, it is interesting to note these figures in order to compare them with losses given for other fungous diseases and insects." Murrill (1908 b:111) states: "The amount of damage done by it, in and about New York City, where it has been most carefully observed, probably reaches a total of between five and ten million dollars." Metcalf and Collins (1911:5) regard $25,000,000 as a conservative estimate of the financial loss from this disease up to 1911. Metcalf (1913:364) states: "The estimate of $25,000,000 made in 1911 as representing the loss up to that time was probably much too conservative. But the total loss to date is insignificant compared with the loss which will ensue if the disease once attacks the fine chestnut timber of the South Appalachians."

SYMPTOMS

With few exceptions every writer on the subject has described the symptoms of the disease, and many writers have published excellent

illustrations. The effects of the disease on the general appearance of the tree are most noticeable during the summer, when the trees are in leaf. In regions where the disease is common, the newly affected limbs and twigs are girdled in large numbers during the summer, and the brown, shriveled leaves are readily seen even at a distance. This most striking symptom is common during July and August, while the healthy parts of the tree are still green.

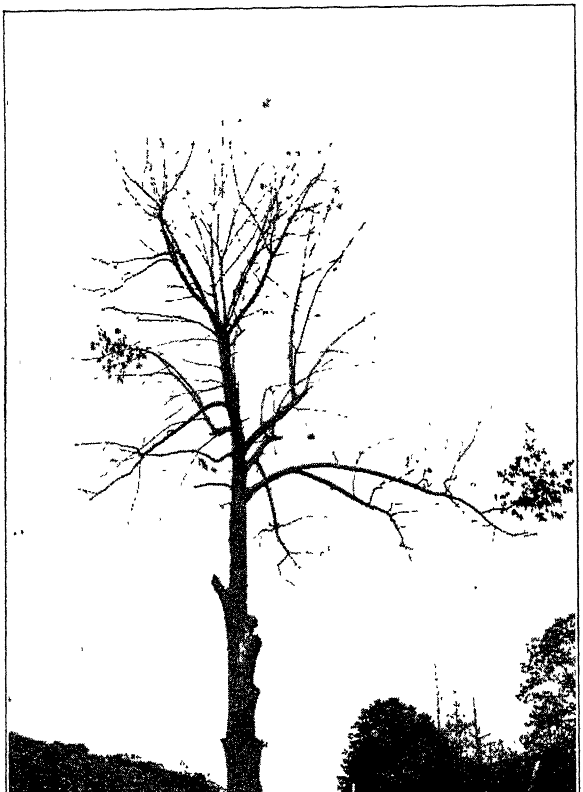

FIG. 79.— *Tree during winter, showing the leaves still clinging to the branches, which have been killed by girdling cankers*

The dead leaves also remain clinging to the limbs during the winter (Fig. 79). If the girdling of a limb is completed during the time when the burs are maturing, the latter often remain on the branches over winter. If, however, the girdling takes place after leaves and burs are shed and before the leaves come out in the spring, the leaves do not attain their full size and are pale and distorted. This is a common symptom in May and June (Fig. 80). Dead limbs without attached leaves or burs are often indications of the presence of the canker disease (Fig. 81). Water sprouts or suckers are commonly developed just below the cankers. Thick clumps of suckers on the trunk (Fig. 82), on the branches, or at the base of the tree, are often the only telltale evidence of a developing canker. Such growths

are very conspicuous the year round. In time they are killed either by the canker's invading the area from which they grow or by the infection of the suckers themselves.

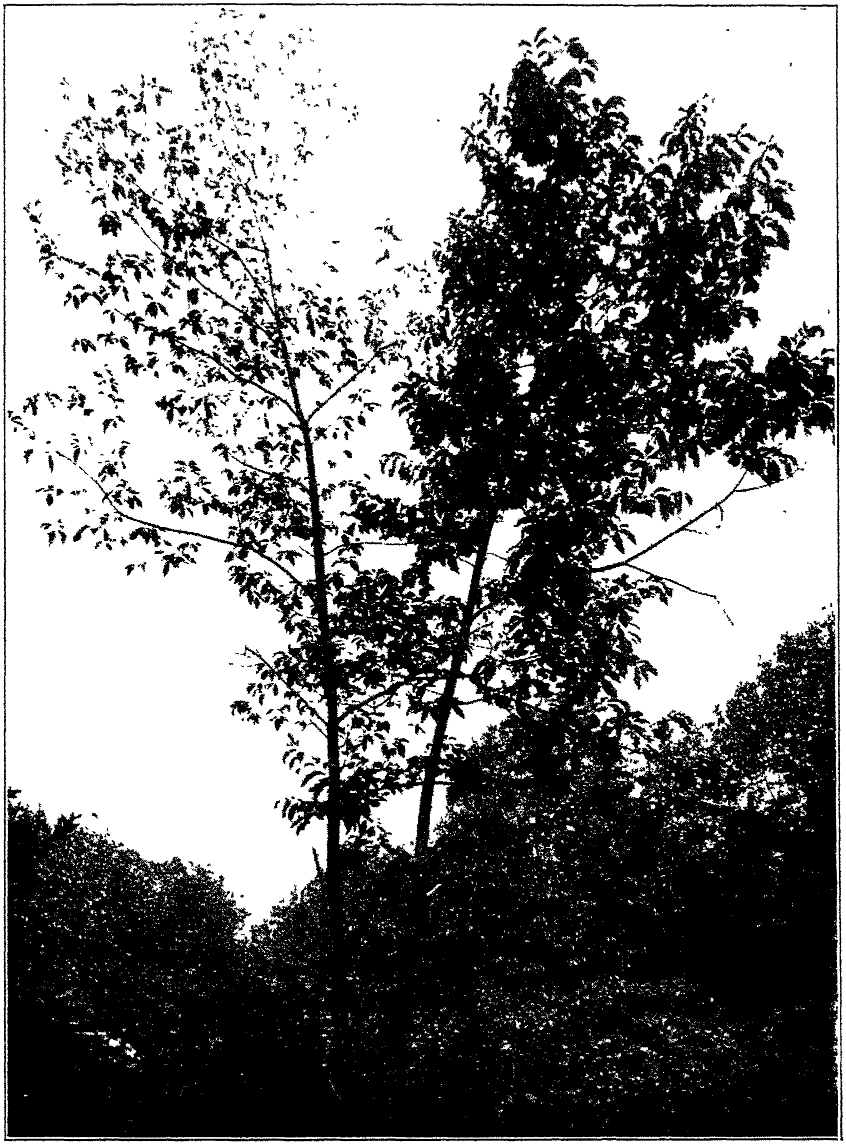

FIG. 80.—*A diseased and a healthy tree in midsummer. Notice the poorly developed leaves on the diseased tree (at the left)*

Cankers on smooth bark are especially conspicuous (Plate XXXVI, frontispiece). They can be seen for a long distance because of their reddish tinge in contrast to the healthy green bark. The cankers are either sunken or swollen diseased areas of the bark (Plate XXXVII). They occur on branches of all sizes — only rarely, however, on first-year twigs. The usual shape of the canker is ellipsoidal, being longer

FIG. 81. — *Chestnut woodland devastated by the canker. Photograph taken in midsummer*

in the direction of the long axis of the limb. The margin of the canker is usually fairly regular, but it may be irregular.

Metcalf (1914) says the cankers formed on the Chinese chestnut become deeper year by year as healthy wood is formed about them, thus causing a condition similar to the European apple-tree canker.

Usually about a month after inoculation the bark of the affected area becomes covered with numerous small pimples. Under moist conditions, following rains, long, twisted, yellow tendrils are extruded from the

TYPES OF CANKERS ON CHESTNUT CAUSED BY ENDOTHIA PARASITICA

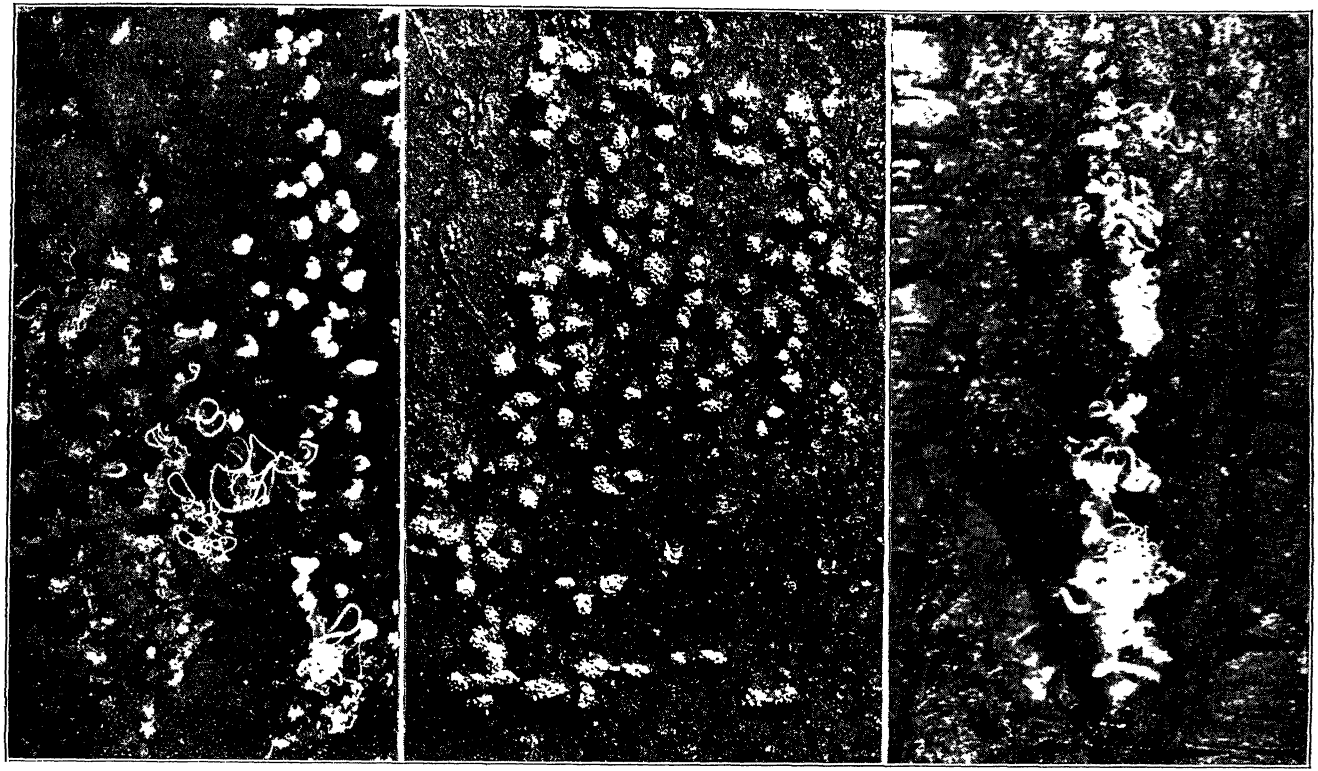

FIG. 1.— *Part of canker showing twisted pycnospore tendrils*

FIG. 2.— *Stromata on smooth bark, showing papillæ, at the tip of which are the ostioles of the perithecia*

FIG. 3.—*Lines of pycnospore tendrils in crevices of rough bark*

EXTERNAL APPEARANCE OF FRUITING STAGES

FANS OF MYCELIUM IN THE CAMBIUM AREA AFTER THE BARK HAS BEEN PEELED OFF

FIG. 1.—*Section of stroma showing mature pycnidium of irregular shape. Pycnidium partly filled with spores*

FIG. 2.—*Longisection of a perithecium partly filled with asci*

FIG. 3.—*Section of stroma showing two empty perithecia with their black necks extending to the ostioles at the surface*

LONGISECTIONS OF STROMATA SHOWING FRUIT BODIES

ruptured apices of these blisters (Plate XXXVIII, Fig. 1). Older and larger cankers have the pimples and the yellow tendrils confined to the margin, while nearer the center reddish-brown pustules have been pushed out through the outer bark. These pustules, when fully developed, measure one sixteenth of an inch or more in diameter and have numerous papillæ on the upper surface, each with a black dot at the tip (Plate XXXVIII, Fig. 2). Cankers on rapidly growing limbs are usually outlined by a distinct ridge of slightly hypertrophied tissue. Where the whole cankered area is hypertrophied the bark usually splits longitudinally (Plate XXXVII). As the canker becomes older the bark splits and cracks, and after a few years it breaks away entirely and leaves the wood bare (Fig. 83). When the tree is thoroughly diseased — and this may take only two or three years after the first infections occur if they are at the top of the tree — the brown pustules cover the bark of the trunk and the branches, giving the tree the distinc-

FIG. 82.—*Water sprouts on the trunks, indicating cankers just above them*

tive brown hue. When the fungus affects rough bark, no shrinking nor swelling nor change in color is evident, and it is only when the yellow tendrils, or later the brown pustules, are produced in the crevices of the bark that an outward indication of the diseased area appears (Plate XXXVIII, Fig. 3).

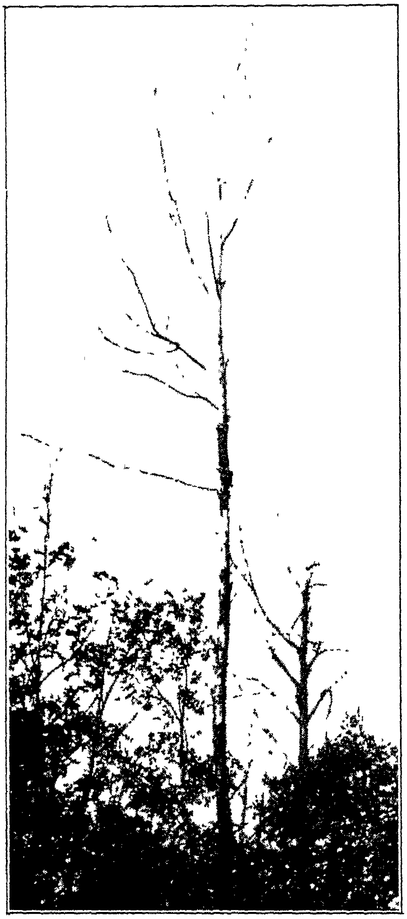

FIG. 83.— *Tree that has been dead for several years, showing the bark falling off in patches and exposing the wood*

By examining the character of the destruction of the bark one may determine other diagnostic characters. When the bark is peeled from the edge of a canker it is found to be flaked with tawny, fan-shaped areas, which, once seen, are easily recognized (Plate XXXIX). The invaded tissue is changed to a light sienna brown and appears in marked contrast to the normal light-colored bark. Thick bark that is affected is reduced to a mass of shreds, which are a uniform dark brown in color. The first layers of wood and the medullary rays also turn brown under the cankered area.

ETIOLOGY

Name of the causal organism

It has been proved by Murrill (1906, a, b, and c) that the Endothia canker of chestnut is produced by a fungus which he refers to the genus Diaporthe, of the Sphaeriales. Believing that it had not been previously described he gave it a new specific name, *parasitica*, recalling its destructive parasitic habit.

Rehm (1907) declares that it belongs among the Hypocreales in the genus Valsonectria, and proposes the combination *Valsonectria parasitica* (Murr.) Rehm.

Clinton (1909:888) quotes Farlow as stating that "it comes more naturally under the genus Endothia, and is closely related to *E. gyrosa*." The latter is a saprophytic species which, as limited by Saccardo, was first described from North Carolina by Schweinitz in 1822 as *Sphaeria*

gyrosa on Fagus and Juglans, and in 1828 by Fries as *S. radicalis* on Fagus (or Quercus) from the same State, and which is found commonly on oaks, chestnuts, and a number of other trees in Europe as well as in America.

Von Hohnel (1909) says that *Diaporthe parasitica* Murr. is identical with *Endothia gyrosa* (Schw.) Fuckel; also that the genus Valsonectria is not different from Endothia, which he would place among the Hypocreales because of its bright-colored stroma rather than in the Sphaeriales where it is usually placed. He gives two reasons why the fungus is an Endothia rather than a Diaporthe: (1) the bright-colored stroma is typical of the former, but not of the latter; (2) the conidial fruit form of Diaporthe is Plenodomus Preuss (Phomopsis Sacc.), while that of Endothia is Endothiella Sacc., characterized by irregular chambers in the stromata, without a definite wall and with small, rod-shaped spermatia.

Clinton (1912 c.79–80), at the Harrisburg Conference in February, 1912, states that he believes *Diaporthe parasitica* to be closely related to *Endothia gyrosa*, but of a different species. In a footnote, written after the conference, he states that he found *E. gyrosa* common as a languishing parasite or saprophyte on chestnuts and oaks in Virginia, North Carolina, and Tennessee; and that it differs from *Diaporthe parasitica* in that the stromata are less luxuriant, and especially that the ascospores are smaller and narrower, but he is not sure "whether these differences are those of a strain, variety, or distinct species." At the same time Farlow (1912 a:74) gives it as his opinion that *Endothia gyrosa* and *Diaporthe parasitica* are identical. Rankin (1912 b:47) states that he found a saprophyte common on the chestnuts in Virginia which is indistinguishable from the canker fungus. So far as the literature shows, Rankin was the first to find this saprophytic Endothia on chestnuts in America.

All the writers quoted above consider *Endothia gyrosa* (Schw.) Fr. and *E. radicalis* (Schw.) de Not. as synonymous. Shear (1912 a) questions their identity, and in the same paper states that there is a specific difference between *Diaporthe parasitica* and *Endothia radicalis* (Schw.). It appears from Shear's later papers (1912 b and 1913 a) that he was applying the latter name to a form with bacilloid spores found commonly in the Southern States, first brought to notice by Farlow (1912 a:74) and later called by Clinton (1912 a) the "linear-spored Endothia."

Farlow (1912 b) in Science repeats his previous statement that *Diaporthe parasitica* and *Endothia radicalis* (European form) are identical, and states that his opinion is shared by von Höhnel and Saccardo.

Since 1909 the generic position of the fungus has not been seriously questioned, all authorities apparently agreeing that it is an Endothia. Outside those already mentioned, the most valid reason for placing the fungus in Endothia rather than in Diaporthe or Valsonectria may be

stated thus: Endothia was erected in 1846, with *Sphaeria gyrosa* Schw. as the type. When the new fungus that causes the canker was studied, it was found to resemble *E. gyrosa* (as defined by Saccardo) so closely that even such authorities as Saccardo, von Hohnel, and Farlow could not distinguish the two species. Also the very few other species that have been referred to this genus resemble these two so closely that no one would think of putting them in different genera. Wherever one is placed they must all go. If one is placed in Diaporthe they must all be placed there, that is, the whole genus must be combined with Diaporthe. But, according to our rules of nomenclature, when the members of two genera are combined they take the name of the species first described, which in this case happens to be an Endothia. Therefore, even if there were not sufficient generic differences to keep the two genera separate, the canker fungus would still be Endothia, not Diaporthe nor Valsonectria — genera which were established many years later. The question from this time on was in regard to the specific name to be applied.

Shear (1912 b), after a summer in Europe, stated that the *Endothia radicalis* of European authors is morphologically identical with *Diaporthe parasitica;* also that the American *Endothia radicalis* (Schw.) is the long-spored form of the Southern States; also that the latter is different from the European *E. radicalis.* He later retracted the first and the second of these statements (1913 a).

Anderson and Anderson (1912 a) made a study of the saprophytic American Endothia, which they found common on chestnuts and oaks in southwestern Pennsylvania, Virginia, West Virginia, and Tennessee. They found marked morphological, biological, and cultural differences between this and the true canker fungus. They consider these differences of specific value, and propose the new combination *Endothia parasitica* (Murr.) for the canker fungus and *E. virginiana* sp. nov. for the saprophytic form. The most noticeable morphological differences are:

E. parasitica	*E. virginiana*
Mycelium forms thick, fan-like mats in the bark and on the cambium	No such mats perceptible
Size of ascospores, 8.6 by 4.5 μ	Size of ascospores, 7 by 2.98 μ
Shape of ascospores, broad: proportion of diameter to length, 1 : 2.7	Shape of ascospores, narrow; proportion of diameter to length, 1 : 1.9
Constriction at septum of ascospores distinct	Constriction very slight, if any
Length of ascus, 51.3 μ	Length of ascus, 34 μ

Biologically, the former is a virulent parasite and the latter a saprophyte. Cultural differences were found on every artificial medium on which the two were grown in pure culture. The reasons given by Anderson and Anderson for creating a new specific name for the saprophyte are: (1) Shear had identified the long-spored southern form as *E. radicalis* and this was entirely different from the species under consideration; (2) an examination of the type material of *E. gyrosa* (Schw.) Fr. in the Schweinitzian herbarium at the Philadelphia Academy of Science, and a comparison with the original description and all the early literature on this fungus, convinced them that it was a form entirely different from any species of Endothia now known; (3) there was no other described species of Endothia besides the above two which closely resembled the fungus that they were studying in western Pennsylvania.

Clinton also studied the relationships of these two forms and found practically the same differences as did the Andersons, besides additional cultural differences; but he considers the differences varietal, not specific. Shortly after the appearance of the paper mentioned in the preceding paragraph, Clinton (1912, a and b) published two papers in which he states that the European Endothia and the American *E. virginiana* Anders. are identical with *E. gyrosa* (Schw.) Fr. He proposes *Endothia gyrosa* var. *parasitica* as the proper name for the canker fungus. He emphasizes especially the difference in the shape of the ascospores, and calls the species the "narrowly-oval-spored" and the variety the "broadly-oval-spored" Endothia.

At about the same time, Pantanelli (1912), in Europe, studied the relationship of the European Endothia to the American canker fungus, and found important morphological, biological, and cultural differences which he considers of specific value; he designates the latter form as *E. parasitica* (Murr.) Anders., and the European form as *E. radicalis* (Schw.) Fr.

Shear (1913 b) examined asci and ascospores of the type specimen of *E. radicalis* (Schw.) from the Fries herbarium at Upsala, Sweden, and found them to correspond with those of *E. virginiana* Anders. and the form discussed by Clinton as *E. gyrosa*.

Shear and Stevens (1913 a) were the last to study in detail the relationships of the species of Endothia. They studied especially the cultural characters, and on nearly every kind of medium tried they found characters by which *E. parasitica* can be distinguished from the other species.

They give as the correct names of the species here under consideration:

1. *Endothia parasitica* (Murr.) Anders., the true canker fungus
2. *Endothia radicalis* (Schw.) de Not., the saprophyte found first on chestnuts in this country by Rankin, later called *E. virginiana* by

the Andersons (1912, a and b), and discussed under *E. gyrosa* by Clinton (1912, a and b) as the "narrowly-oval-spored Endothia"

3. *E. gyrosa* (Schw.) Fr., the bacilloid-spored southern form, which Shear (1912 b and 1913 a) had previously called *E. radicalis* (Schw.) and Clinton had discussed under the name of *E. radicalis* (Schw.) Farl., or the "linear-spored Endothia"

The last of the three need not be considered especially at this time, since it has not been confused with the true canker fungus. Finding no intermediate forms between the first two, Shear and Stevens conclude that "unless such intergrading forms should be discovered later, there seems to be no way of escaping the conclusion that the two organisms are specifically distinct, according to the most conservative taxonomic standard of species prevailing at present in mycology."

In this publication the canker fungus will be referred to as *Endothia parasitica*. The complete synonymy is as follows:

Endothia parasitica (Murr.) Anders. Phytopath. **2**:210, 262. December, 1912

Diaporthe parasitica Murrill. Torreya **6**·189. 1906

Valsonectria parasitica (Murr.) Rehm. Ann. myc. **5**:210. 1907. Ascom. exs., fasc. 39, no. 1710

Endothia gyrosa var. *parasitica* (Murr.) Clinton. Science **36**:913. December, 1912

Concerning the pycnidial stage of the fungus, it was first referred to the genus Cytospora by Patterson (Clinton 1909:879), and shortly afterward by Clinton (1909) to the same genus. Since that time it has frequently been referred to in the literature under that name. Reasons for considering this disposition of it as incorrect will be given in the discussion of morphology and life history. In 1906 Saccardo (Ann. myc. **4**:272) erected the genus Endothiella, based on the pycnidial form of *Endothia gyrosa* (*E. radicalis* [Schw.] de Not., according to Shear). Since the imperfect stages of our American Endothiae are practically indistinguishable, it is evident that the pycnidial form of *E. parasitica* should be referred to that genus, if there is ever any need of considering it apart from the perfect stage.

History of the pathogen

When the disease was first noticed in this country in 1904 it was a comparatively simple matter to determine the association of the fungus with it. But where did this fungus come from, and why had it not been noticed before? There were only two possibilities: (1) either the fungus had always been here, but was now for the first time brought to notice; or

(2) it was an introduced species. When a fungus produces a sudden and destructive epiphytotic the presumption is that it has been introduced from some foreign country — a presumption that is supported by numerous well-known analogous cases in the past. But, on an investigation of conditions in other countries, no record of a similar disease of the chestnut could be found. This, however, does not invalidate the importation theory, since it is a fact well-known to plant pathologists that a fungus may be an inconspicuous and comparatively harmless parasite in its native country and yet may produce a destructive epiphytotic on being taken to another country.

This theory was first advanced by Metcalf (1908 a). Since he was unable to find any record of the occurrence of the disease in this country, and since he found the Japanese chestnuts more or less immune, he suggested that the fungus was a native of Japan and had been introduced here on imported trees. The presumption would be that, spreading to our native chestnuts, the fungus found these less resistant and more favorable to its growth; hence its rapid spread throughout the eastern States. In February, 1912, just previous to the Harrisburg Conference, Metcalf (1912 b:77–78) discussed his theory in part as follows:

"My own working hypothesis is, that the parasite is an importation from some country other than North America. The resistance of the Japanese and Korean chestnuts, coupled with the fact that the Japanese chestnut has been extensively imported and grown in that part of the country whence the disease appears to have spread, suggests that Eastern Asia may be the home of this parasite. . . . That the parasite has come from Europe seems less probable, in view of the fact that, according to Pantanelli, as well as according to my own inoculations under greenhouse conditions, the European chestnuts show no resistance to the disease. . . .

"The main fact in support of a foreign origin of the disease is its unquestionable spread in all directions from the vicinity of New York City. It is further suggestive that the oldest centers of infection located outside the vicinity of New York City — Bedford county, Virginia, and Baltimore county, Maryland — contained chestnut orchards with Japanese chestnut trees, possibly also European varieties. If *Diaporthe parasitica* is a native fungus, or has evolved from a native saprophyte, it is necessary to assume that the saprophyte was very limited in range, or that the evolution to a condition of parasitism occurred in only one, or at most a very few localities, or that there is a chronological sequence in its evolution proportional to its distance from New York City. Any of these assumptions are a severe tax on the scientific imagination."

Clinton (1909, 1911, 1912 a, 1912 c, 1913) holds to the opposite view;

that is, that the fungus has always been in this country as an inconspicuous saprophyte or a weak parasite, and that it became virulent about 1904 because the trees were in a weakened condition due to winter injuries and unfavorable weather conditions, as well as faulty silvicultural methods such as continuous coppicing. He briefly sums up his reasons for his theory as follows (1913:416–417):

"The writer's reasons for believing the chestnut blight is native to this country may be summarized as follows: (1) It has never been found in any other country. (2) It is very closely related to *Endothia gyrosa*, apparently developing from it as a distinct variety, and this species is a native fungus in this country as well as in Europe. (3) The limits of distribution of *E. gyrosa* and the chestnut blight overlap at least in the region covered by Washington, D. C., to southern Pennsylvania, while *E. gyrosa* occurs south of this common area and the chestnut blight north of it. (4) We have previously had serious troubles of chestnut trees in this country, and there seems to have been a continued northward movement of these, culminating in the recent trouble in the northern limit. While the chestnut blight has been definitely connected only with this last trouble, the previous ones have never been really explained. (5) The suddenness, et cetera, of the recent blight outbreak has been adequately explained by the writer through the unusual environmental conditions that have weakened the chestnuts in the general regions where the outbreak has occurred. (6) The fact that the chestnut blight fungus was never reported before this outbreak is no more difficult to explain than the fact that *E. gyrosa* had never been reported on chestnut in this country until by the writer a year ago, and yet this is a native fungus widely distributed on chestnut in the South, and has been known there on other hosts since 1822, when described by Schweinitz. They both were, in fact, merely overlooked on the chestnut. (7) Our cultures of *E. gyrosa* vary more from their normal type than do those of the variety *parasitica*, and some of these have varied somewhat toward the variety *parasitica* type. This, however, may have been due in part to bacterial contamination, et cetera."

The strong point in Clinton's argument, and the missing link in Metcalf's, was that the fungus could not be found in eastern Asia. But this link was supplied during the last year, when Fairchild (1913) reported the finding of the fungus in northern China by Meyer, an agricultural explorer of the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture. As had been expected, the fungus was found to be only weakly parasitic in that country, judging from Meyer's letter, which is quoted here only in part:

"The blight does not by far do as much damage to Chinese chestnut

trees as to the American ones. Not a single tree could be found which had been killed entirely by this disease, although there might have been such trees which had been removed by the ever active and economic Chinese farmers. Dead limbs, however, were often seen and many a saw wound showed where limbs had been removed. . . . The wounds on the bigger majority of the trees were in the process of healing."

Shear and Stevens (1913 b) made cultures from the Chinese specimens and found that all the cultural characters are identical with those of *Endothia parasitica*. Spore measurements agreed very closely, and inoculations made on native American chestnuts produced typical cankers. The writers of this bulletin have grown the Chinese fungus in culture and cannot distinguish it from the American chestnut-canker fungus.

It may now be regarded as practically certain that the early home of *Endothia parasitica* was the Orient.

Morphology

Stromata

Cankers of a season's growth or older show numerous orange-colored or reddish-brown, erumpent and projecting, stromata (Plate XXXVII). On smooth bark the stromata are usually elongated horizontally and average about 2.4 by 1.2 millimeters, by 1.3 millimeter in depth. The part beneath the ruptured cork layer is flattened out on the collenchyma and is broader than the exposed part (Figs. 84 and 85). The stromata, however, vary widely in size with environment and season; they become much larger in moist situations than in dry surroundings where they are exposed to desiccation. On old, rough bark they do not occur singly, as shown in Plate XXXVII, but are found only in the crevices of the bark, often united in solid lines several inches long so that they apparently form one long stroma.

The color varies with age, being sulfur yellow at first, later becoming orange, reddish-brown, and finally cinnamon-brown on the surface, but always lighter-colored on the inside When in a shaded and moist location — as, for example, on the underside of a log — the stromata remain light yellow.

In the fresh condition the stromata are soft, dry, subcoriaceous, easily torn apart, and of rather loose, indefinite outline. A cross section shows that the center of the stroma is composed of a comparatively loose tangle of branched and septate hyphæ, containing yellow pigment. Throughout the basal parts are scattered stone cells, bast fibers, and remnants of the walls of collenchyma cells. The entire exposed surface of the stroma is covered by a rind layer, in which the hyphal cells are shorter and thicker, almost or quite isodiametric, and with heavier walls than in the interior.

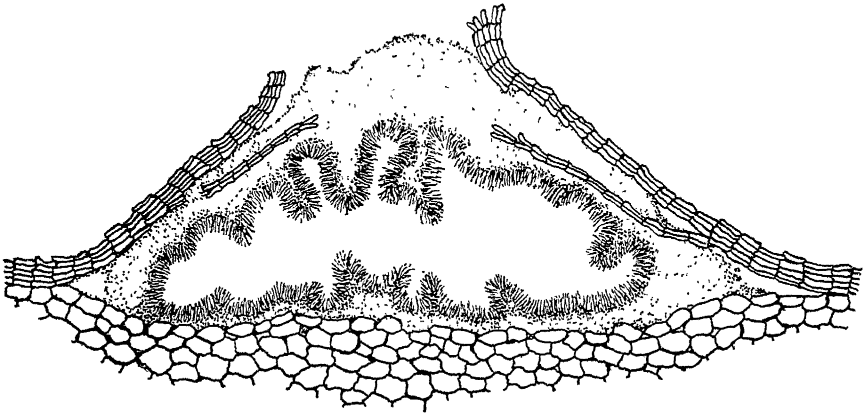

FIG. 84.— *Cross section (diagrammatic) of a mature pycnidium under the cork layer, ostiole not shown. After Heald*

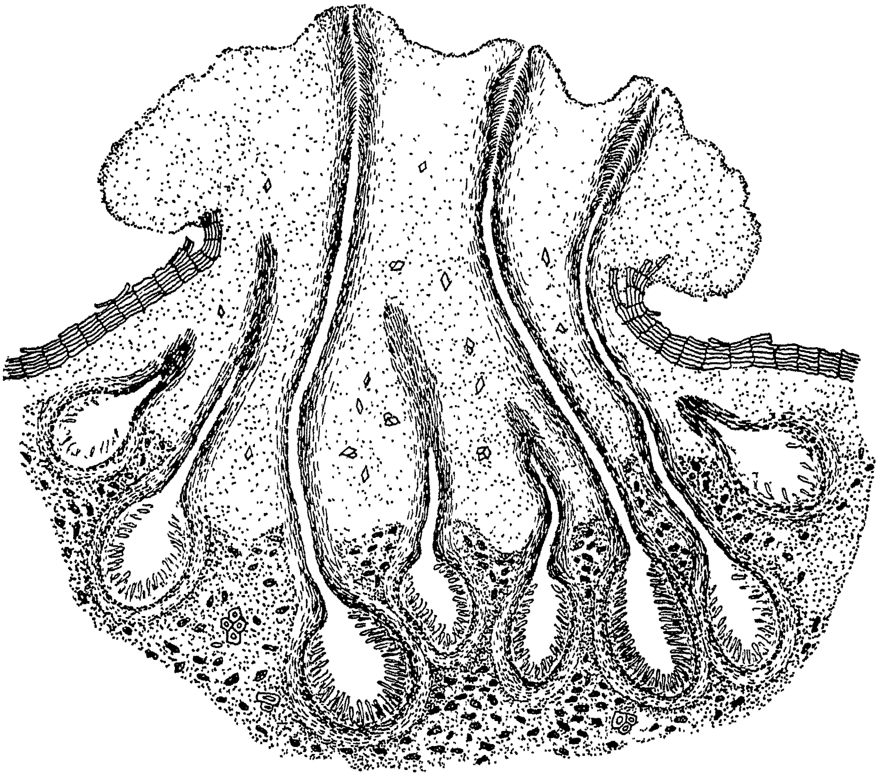

FIG. 85.— *Cross section (diagrammatic) of a stroma, showing mature perithecia. After Heald*

They are closely crowded together, so that in cross section they appear to make up a pseudoparenchymatous tissue. These cells are more densely filled with protoplasm, and contain more pigment, than the interior cells.

Pycnidia

On smooth-bark, young cankers, especially in the summer, the outer cork layer is raised in numerous little blisters, with slender, yellow, waxy tendrils curling from their ruptured apices (Plate XXXVIII, Fig. 1). Under each blister is a single somewhat globose pycnidium, surrounded by a scanty, loose growth of white or slightly yellowish mycelium. There is as yet no definite stroma. The wall of the pycnidium is composed of closely tangled hyphæ; that is, it is not a definite pseudoparenchymatous wall. The cavity may be a fourth of a millimeter in diameter and is almost round in cross section at first, becoming irregular only with age. The conidiophores form a dense, brush-like fringe and extend directly out into the cavity from every point of the wall (Fig. 86). They are of uneven lengths, the majority being 20 to 40 μ long, and are about 1.5 μ in diameter. They may be simple or branched. Spores are cut off successively from the conidiophores or their branches and soon fill the cavity, but, since the production of spores does not cease when the cavity is filled, they are forced out through an irregular ostiole at the top in yellow tendrils. These tendrils take on a reddish tinge as they become old. They vary in thickness from the diameter of a hair to half a millimeter, and in length from a millimeter to three or four centimeters. They occur singly and are usually spirally twisted into one or more coils (Plate XXXVIII, Fig. 1).

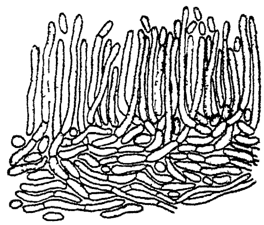

FIG. 86. — *Section of the wall of a very young pycnidium, showing the conidiophores, with the manner of their origin from the hyphæ. Conidiophores become branched in older pycnidia*

The older pycnidia contained in mature stromata differ from these in some respects. The cavity is convoluted or labyrinthiform, and irregular (Fig. 84, and Plate XL, Fig. 1). When cross sections of these stromata are cut, a single section usually shows a number of cavities which do not appear to be connected; but if the entire stroma is cut into serial sections it is found to contain but a single pycnidium with a number of communicating chambers. Only rarely have the writers found stromata containing more than one pycnidium. This stage of the fungus has been referred to the genus Cytospora, on the erroneous idea of a stroma containing many pycnidia. The cavity of the labyrinthiform type of pycnidium often becomes as much as a milli-

meter in diameter. The spore horns from this type are also usually much stouter than those from the former type, and on the bark of old trees, where they arise from lines of confluent stromata in the crevices, a whole line of them may be united in a comb-like manner. The spore horns of both types are usually flat or irregular in cross section. This accounts largely for the way in which they curl. When dry they are hard and brittle and not easily detached or broken.

Another form of pycnidia occurs on cut ends of stumps and logs, and also on both the wood and the inside of the bark where the latter has broken loose. These are superficial, single pycnidia (Fig. 87). A favorite place for them is on the inside of the bark where it has drawn away from the stump around the top, after the tree has been cut. Also, when a log or a stump on which there was a canker is peeled, these pycnidia develop on the surface very quickly. Their production is largely dependent on the water supply; this is illustrated by the fact that in dry weather they develop on the lower side of a log lying on the ground, but not on the upper side. In moist, shaded places they are long pear-shaped or conical, as shown in Fig. 87, or the base may be flattened out slightly on the substratum; but on tops of stumps — where they occur abundantly on the outermost four or five annual rings and where the supply of moisture is not constant — they are flattened out on the substratum and do not stand out free as shown in the figure, and they also have more of a tendency to run together. In color they are deeper red than the stromata, but have light yellow, conspicuous, beak-like ostioles. They are surrounded by no stroma whatever and stand out free except as stated above. They measure about a quarter of a millimeter in diameter and the same in height. The outer wall is perfectly smooth as seen under a hand lens. Often several pycnidia unite, but their ostioles remain distinct and give the appearance of a single pycnidium with several ostioles.

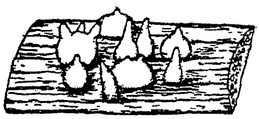

FIG. 87.— *Superficial pycnidia on wood, developed in a moist situation*

Pycnospores

The yellow tendrils are composed entirely of small, hyaline spores that are held together by a sticky substance the nature of which has not been carefully investigated. When the tendril is placed in water, it first swells considerably, then the binding substance dissolves and the spores float away free from one another. The spores average about 1.28 by 3.56 μ in size, and are oblong or cylindrical with rounded ends, or slightly oval, usually straight but sometimes slightly curved. The fact that they

are not typically curved is an additional reason why this stage should not be referred to Cytospora. The spore membrane is thin and smooth. The spores are filled with dense homogeneous protoplasm, and each spore contains a single small, elongated nucleus near the center. There is also a polar body in each end.

Perithecia

The mature stromata on older cankers have numerous projecting papillæ on the surface (Plate XXXVIII, Fig. 2). The black speck at the tip of each papilla is the opening of a perithecium, the body of which is located down in the bottom of the stroma and is connected with the apex by a long, black neck. These papillæ may scarcely project above the surface of the stroma, or, on the other hand, they may be a

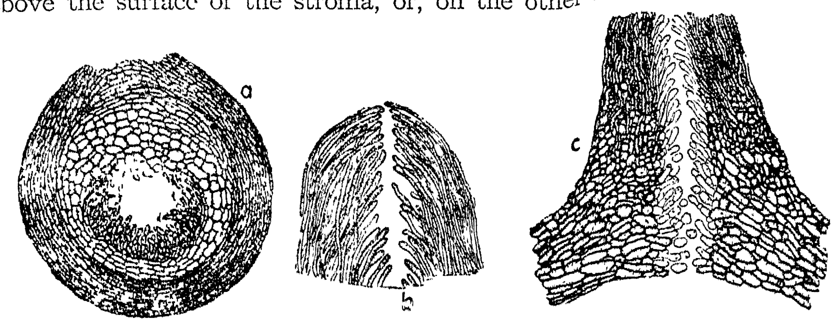

Fig. 88. - *Stages in the development of the perithecium*

a, Cross section at the stage when the cavity is occupied by young paraphyses. The neck is not shown

b, Tip of the neck in cross section as it appears, pushing up through the stroma at the same stage as shown in (a)

c, Lower part of neck and canal when the perithecium is almost mature, showing periphyses projecting into the canal

millimeter or more in length. They are longer in moist, shaded places than in dry, lighter surroundings. There are commonly fifteen to thirty perithecia in a stroma, but the number varies greatly, over forty having been counted in some cases. In Fig. 85 (page 558) and in Plate XL, Figs. 2 and 3, perithecia in longisection are shown. As seen under the hand lens the wall of the body of a perithecium is gray or lead-colored, while the neck is jet black and shining like anthracite. The mature perithecia measure about 350 to 400 μ in diameter and are mostly spherical, but the shape is often modified by pressure of surrounding perithecia.

Since the perithecia are always in the bottom of the stroma next to the host tissue, the length of the neck varies with the luxuriance of the stroma and the length of the papilla; but, in general, it is four to six times the diameter of the body. The black wall of the neck is composed of densely

interwoven, septate, heavy-walled hyphæ running longitudinally with the long axis of the neck.

Branches of the same hyphæ project out free into the canal and upward toward the tip (Fig. 88, b). They are thin-walled, and react toward stains in a manner different from that of the other tissues. They are especially prominent at the tip of the neck. They are the periphyses.

In cross section the wall of the body is seen to be composed of ten or twelve layers of flattened, heavy-walled cells, very compact and pseudoparenchymatous (Fig. 88, a). Inside this there is a region of two or three layers of thin-walled cells, from the inner surface of the basal part of which the asci grow out into the cavity.

Asci

When the perithecium has become mature the entire cavity is filled with asci — the older, mature ones in the center, and younger ones around the walls. Mature asci are shown in Fig. 89, b, c, and d. They are broadly clavate or oblong, and each ascus contains eight spores in a matrix of epiplasm. The average size of one hundred and fifty asci measured by the writers was 51.2 by 8.9 μ. The arrangement of the spores is irregularly uniseriate or sub-biseriate; but there is little uniformity in this arrangement, since two asci can hardly be found in which the spores are oriented alike. The wall of the ascus is delicate and hyaline, and for this reason is hard to make out in its entirety in unstained mounts. There is a thickened ring about the upper end of the lumen of the ascus which is prominent and shows peculiar staining reactions. When the ascus is lying flat on the slide, the ring appears in optical section as two highly refractive disks (Fig. 89, c).

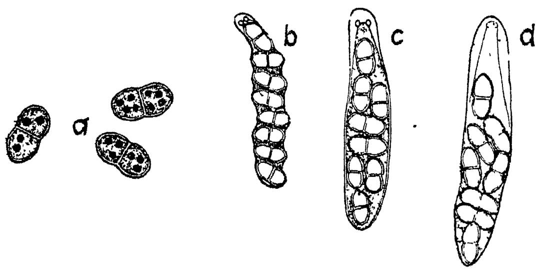

FIG. 89.— *Ascospores and asci*
a, Three ascospores showing nuclei
b, Ascus with spores when dry
c and d, Asci after swelling in water

Ascospores

The ascospores (Fig. 89, a) are oblong to oval with rounded or blunt-pointed ends, two-celled, constricted at the septa when mature, and on the average about 4.5 by 8.6 μ in size. The walls are thicker than those of the conidia; the septum is distinct and is composed of the same material as the walls. The spores are filled with dense homogeneous protoplasm;

only occasionally have anything like oil globules or vacuoles been seen. Each cell of a spore contains two to four nuclei. Like the conidia, the ascospores have a sticky coating on the outside.

Mycelium

The individual hyphæ are branched, septate threads, the branching being always monopodial, and usually not more than one branch is produced from a single cell. The hyphæ are not of uniform diameter, but vary from 1.5 to 12 μ, and the cells vary from 20 to 50 μ in length. Each cell contains several small nuclei. On most culture media the mycelium becomes yellow after a few days, due to the production of a pigment. The pigment is soluble in alcohol and alkalies, and insoluble in acids. In alkaline solutions the pigment becomes purple. It is a chemical compound belonging to the group known as aurines.

A character of this species which distinguishes it from all other related fungi is the presence in the diseased bark and in the cambium of fan-like mats of mycelium (Plate XXXIX). Each mat consists of a number of bundles of parallel hyphæ diverging from a single point like the rays of a fan. They are flat because they have to squeeze between the bast-fiber zones. The edges of the fans are fairly regular and are surrounded by a darker gelatinous band of disintegrating host cells. The fans vary in length from a millimeter to two or three centimeters. The young ones on the advancing edge are pure white, but the older ones become light yellow or buff. The hyphæ composing each ray branch only sparsely, and are more uniform in diameter than those in agar culture. They do not anastomose in any way.

Pathogenicity

On Castanea dentata

Murrill (1906 a) proved that *Endothia parasitica* is pathogenic on the American chestnut. This fact is so easy of demonstration that it has never been questioned since that time. Constant association of the fungus with the canker is readily noticed by all investigators. The fungus has been isolated and grown in pure cultures by a number of pathologists. Inoculations from pure cultures and the production of typical cankers are reported first by Murrill and later by various others. The writers of this bulletin have separately carried out Koch's four rules of proof many times, in New York and Pennsylvania.

On other species of Castanea

Metcalf (1908 a), after having failed to produce the disease by inoculations on Japanese chestnuts in the field, states that this variety is immune.

Murrill (1908 a), however, found cankers on Japanese chestnuts. Clinton (1913:375), after having failed to produce the disease on a Japanese tree inoculated in sixteen different places, states that this variety shows more or less immunity. Metcalf (1914:16), in his latest publication, says. " The Japanese chestnut is highly resistant, and certain strains apparently immune. . . . . . At present we do not know exactly what the Japanese chestnut is; most of the trees that pass under this name in the American market appear to be hybrids with the American or other varieties."

Pantanelli (1911) and Metcalf (1912 b) proved by inoculation that the European chestnuts are not immune.

Murrill (1908 a) found the chinquapin, *Castanea pumila*, attacked.

Morris (Clinton 1913.376) reports that the Chinese and northern Japanese and Corean varieties show decided resistance. Meyer, as stated by Fairchild (1913), finds that the chestnut trees in northern China are not immune, but that they suffer less than do the trees in America. Observations by Morris (1914) and Van Fleet (1914) on the relative immunity of hybrids have been noted above, under the discussion of hosts.

In general, no species nor variety of the genus Castanea has been proved to be immune, but some of the oriental varieties show a certain degree of resistance.

On trees outside the genus Castanea

Fulton (1912:53) reports *Endothia parasitica* on *Quercus alba* and *Q. velutina*, but considers it entirely saprophytic. Clinton (1913:377) adds *Quercus rubra* to the list, but does not believe that the fungus is ever an aggressive parasite on the oaks.

Anderson and Babcock (1913) made cross inoculations, and they discuss this phase in detail. The results of their experiments may be summarized as follows: The fungus was found growing naturally in the woods on *Quercus velutina*, *Q. alba*, *Q. prinus*, *Rhus typhina*, *Acer rubrum*, and *Carya ovata*. Only on the white oak did it seem to have established parasitic relations. (See also Rankin, 1914.) It was isolated from all of these except *Q. prinus*, and when grown in pure culture it appeared identical with the strains from the chestnut. The strains from *Quercus velutina*, *Q. alba*, *Rhus typhina*, and *Acer rubrum* produced typical cankers when inoculated back on chestnuts. The others were undoubtedly *Endothia parasitica*, judging from cultural characters, although no cross inoculations were made. Inoculations with the fungus isolated from chestnut were made on *Quercus prinus*, *Q. velutina*, *Q. alba*, *Q. coccinea*, *Rhus typhina*, *Acer rubrum*, *Liriodendron tulipifera*, and *Carya ovata*. Two trees of Rhus

were girdled and killed by the growth of the fungus. It grew and produced spore horns also, on the wounded tissue at the point of inoculation, on all the others except the maple and the tulip. On *Quercus alba* and *Q. prinus* the cankers continued to spread for several weeks, and fan-shaped mats of mycelium were found under the bark. From the fact that such mats are never found, even on the chestnut, except where the parasite is invading living tissue, it was decided that in these cases, at least, it had established parasitic relations. None of these trees were killed. The fungus was reisolated from all these hosts, and in culture proved to be the same as that isolated from chestnuts.

It may safely be said that at present the canker fungus is not a serious menace to any other forest tree except the chestnut.

Life history

Germination of pycnospores

The pycnospores cannot be made to germinate in pure water. The writers have found the most satisfactory medium for this purpose to be a decoct on made by boiling chestnut bark. The spores will germinate also on sterilized twigs of a large number of trees, on various nutrient media, and even on humus alone; but these media are not favorable for observation of the process under the microscope.

The time required for germination varies with the temperature. Fulton (1912 : 52) states that he found conidia germinated best at a temperature of 60° F., and distinctly less rapidly at temperatures 10° below or above that point. The writers obtained the most rapid germination at 89° F., the shortest time for the appearance of germ tubes being twelve hours. At temperatures ranging from 60° to 75° F., germination occurs in eighteen to thirty-six hours; at lower temperatures the process often requires four or five days. From this it appears that the warm periods of summer are the most favorable for infection by pycnospores. All attempts to produce the disease by inoculating with pycnospores in winter have failed.

The process of germination begins with an enormous swelling of the spores. Spores averaging 1.28 by 3.56 μ before germination, were found, at the end of eighteen hours in chestnut-bark decoction, to average 6.86 by 10.53 μ, the largest observed being 9.05 by 14.48 μ — representing an increase in volume of over one hundred times that of the original spore. A germ tube grows out from one end, and usually this is followed later by a second one from the opposite end. The rate of growth and the manner of septation and branching of the germ tube are best understood by reference to the series of camera lucida drawings of a single spore at short intervals, reproduced in Fig. 90. The swelling of the spores is due, not merely to a mechanical imbibition of water, but also to a process of growth.

Pycnospores stained just before the germ tube is started show that the increase in size is accompanied by active nuc'ear division, two to six

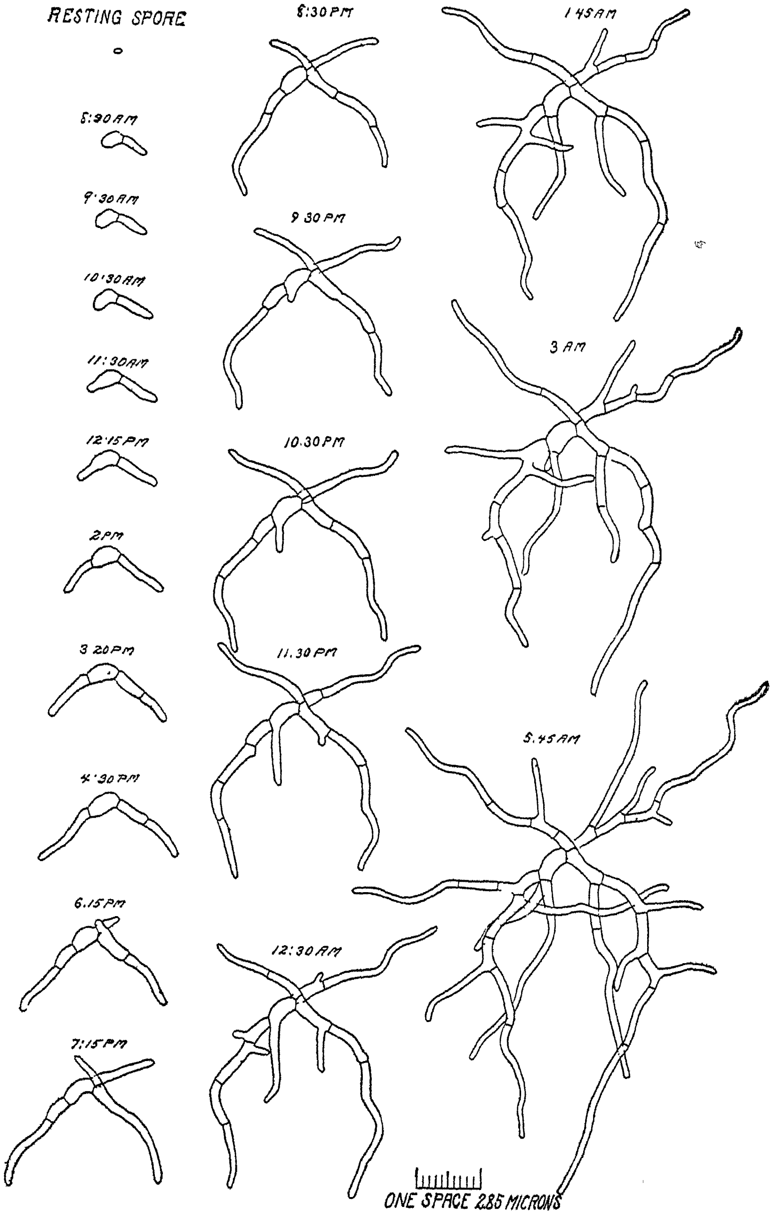

FIG. 90.— *Successive stages in the germination of a pycnospore*

nuclei then being present. The nuclei pass out into the germ tubes almost as soon as they start. The wall, also, has increased in thickness until it almost equals the diameter of the resting spore

Germination of ascospores

Unlike the pycnospores, the ascospores germinate readily in pure water. They do not require a period of rest, but germinate directly after maturity if placed under proper conditions. The time required for the process to begin after the ascospores are placed in water is much shorter than for pycnospores, being about six to twelve hours at room temperature. In regard to the effect of temperature on germination, Fulton (1912:52) says: "Ascospores germinate best at a temperature of about 70° F., but a good percentage of germination occurs at 85° and 45° F. Even at 38° F. the germination of ascospores was 25 per cent in the first twenty-four hours and reached 70 per cent in three days."

Like the pycnospores, the ascospores swell before germination, but not to so great an extent. The first germ tube usually appears at the end — only occasionally being lateral; the next one comes from the other cell; and these are followed by a second one from each of the cells, making a total of four germ tubes. Their order of appearance, size, and manner of septation and branching are best understood by reference to the drawings of successive stages in Fig. 91. The germ tubes from the ascospores grow much more vigorously than do those from the pycnospores. By sowing ascospores on chestnut-bark agar, mature pycnidia have been produced in five days.

Vitality and longevity of the spores

Pycnospores.— Reasoning from analogy with what is known of the vegetative spores of many other fungi, one would not expect the pycnospores to survive winter conditions; but the fact is quite the contrary. During each month of the winter of 1912–1913, spores were collected in the woods from spore horns, from pycnidia imbedded in the stromata, and from superficial pycnidia on wood, and in every test more than fifty per cent of the spores germinated. It appears, then, that winter conditions have very little effect on the viability of the pycnospores. Heald and Gardner (1913 a) also find that pycnospores can be subjected to freezing temperatures for considerable periods without losing their viability.

The longevity of the conidia varies greatly with the way in which they are kept. Spore horns collected and kept dry in the laboratory and tested each month for germination showed very little diminution in the percentage of viable spores at the end of one year. On the other hand, when the spore horns were dissolved in water and the water was allowed

to evaporate, leaving the spores in a separated condition on the slide, they did not retain their viability longer than a month. The difference

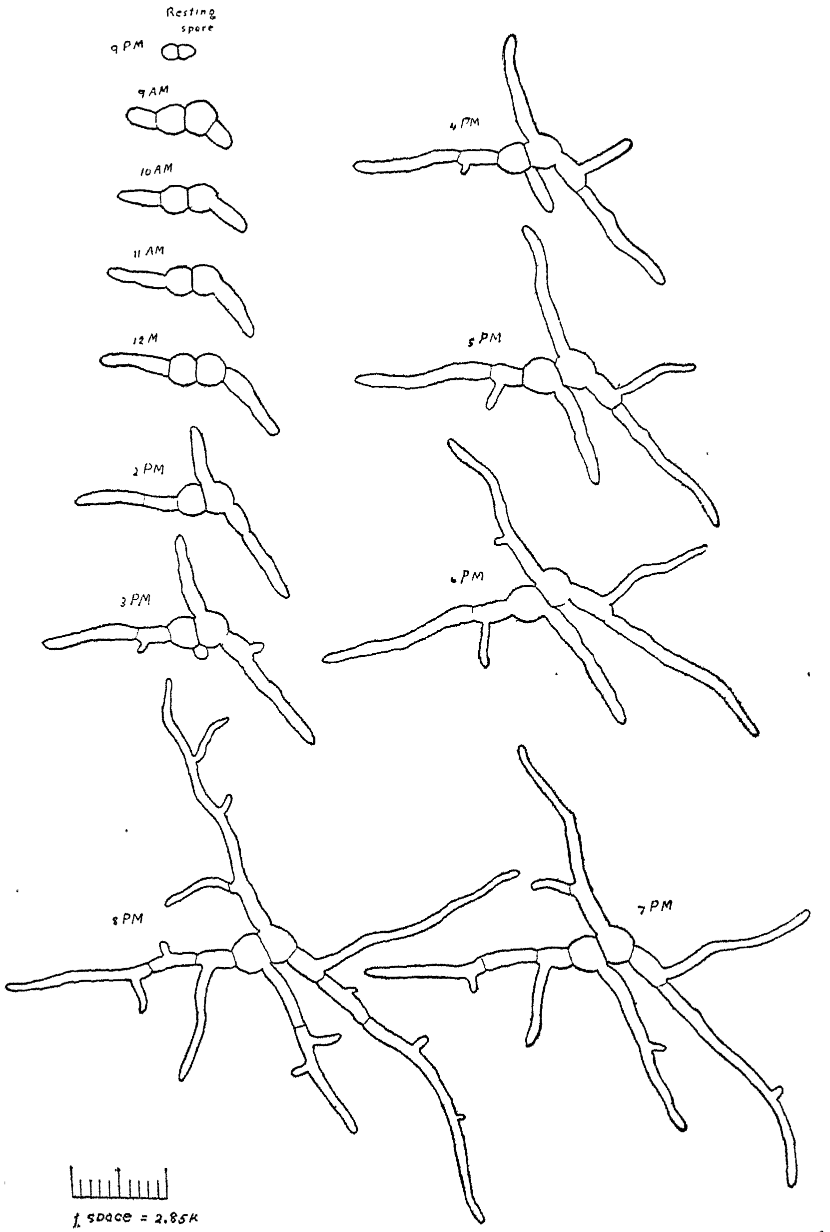

FIG. 91.— *Successive stages in the germination of an ascospore*

has not been explained satisfactorily. It would suggest that possibly the gelatinous substance which binds the spores together in the tendrils may serve also as a protective covering Gardner (1914), however, finds that when washed down into the soil at the base of the tree the spores retain their viability in every case, in large numbers, until the next rain. Even when such soil is taken into the laboratory and kept dry, he has found the spores still alive at the end of one hundred and nineteen days.

Ascospores.— These were also collected and tested during each month of the winter, but apparently winter conditions had no effect on their viability. Their longevity also seems to vary with the amount of aggregation and exposure. In one series of experiments, ascospores ejected from perithecia were caught on slides and stored in a dry place. Tests showed that the percentage of viable spores decreased each month, until, at the end of five months and six days, none of the spores could be made to germinate. In Bulletin 9 of the Pennsylvania Chestnut Tree Blight Commission, however, it is stated that when the ascospores are washed and then dried they are very sensitive to desiccation, and that " drying alone has been found to kill as many as ninety-four per cent in certain tests." In another series of experiments made by the writers of this bulletin, bark containing stromata with mature perithecia was stored in a dry place and germination tests were made from spores taken from these perithecia each month. At the end of one year very little diminution in the percentage of germination could be seen. In another series of experiments, a large percentage of the ascospores similarly stored germinated after eighteen months, while ascospores from material kept for thirty-one months produced only primary and secondary buds and no germ tubes nor mycelium.

Inoculation and infection

The inoculum.— The disease may be produced on healthy trees by introducing into the bark (1) pieces of diseased bark or wood from other trees, (2) bits of agar or other culture media containing the mycelium in pure culture, (3) pycnospores, either as dry spore horns or suspended in water, (4) ascospores suspended in water or dry. The writers have used all of these in producing hundreds of cankers. The highest percentage of infection was obtained from the first, the next highest from the second; very little difference was noticed in the last two, which have been used more extensively and which best imitate the process as it occurs in nature.

Necessity of a wound.— Murrill (1906 a) failed to secure infection as long as " the thin brown layer of cortex remained intact," and was therefore of the opinion that wounds are necessary; but he also suggested the possibility of lenticels being channels of entrance. Metcalf and Collins (1910) state that " the parasite can enter without visible breaks

in the bark, but wounds form the usual means of entrance." Anderson and Babcock (1913) were unable to produce the disease by inoculating with spores without making wounds.

At Napanoch, New York, glass rings were affixed to healthy, smooth bark, which was then sprayed with a suspension of ascospores. The rings were then closed in order to secure moisture conditions favorable for germination. The purpose of the experiment was to see whether infection could take place through lenticels. Forty-nine inoculations made in this way gave negative results. In another set of experiments the rings were placed over natural cracks — which are abundant on heavy-bark trees in spring and early summer, due to the rapid growth of the trees — and these were inoculated as above. The fourteen inoculations made in this way gave negative results. In a supplementary set of experiments, ascospores were sprayed on one hundred and ninety of these cracks and were not protected in any way. All but four gave negative results. In still another set, twenty pieces of bark containing perithecia were placed so that the ascospores would be ejected during rains into these natural cracks. No infection resulted.

As is indicated later under another head, the fungus appears to be incapable of effecting any change in the cork tissue. It should be kept in mind, also, that even when the bark appears sound it may contain small punctures or abrasions which could easily escape notice; and that, unless the point of inoculation is well protected, wounds may be produced subsequent to inoculation which are not taken into account by the experimenter. It is evident, then, that at most the cases in which the fungus enters without an abrasion must be so rare as to be negligible.

Agents that produce the wounds.— When the disease was first brought to notice, Murrill (1906 a: 151–152) suggested a number of agents that might be responsible for the wounds that give entrance to the parasite — such as lumbermen, nut-gatherers, winter injury, the green fly, the twig-borer, squirrels, birds, insects, mice, moles, and rabbits. Later (1906 b) he suggests dead twigs as a channel of entrance, since he often finds these at the center of young cankers.

Metcalf and Collins (1911: 10) believe that insects are responsible for most of the wounds: "When the spores have once been carried to a healthy tree, they may develop in any sort of hole in the bark which is reasonably moist. These may be wounds or mechanical injuries, but by far the most common place of infection is a tunnel made by a borer. . . . In many parts of the country where the disease is prevalent there is very direct evidence that bark borers, and particularly the two-lined chestnut borer (*Agrilus bilineatus*), are directly associated in this way with ninety per cent or more of all cases of this disease." Ruggles (1913) points out

that Metcalf and Collins probably had in mind the tunnels produced by the bast-miner, an undetermined species.

Anderson and Babcock (1913) and Rankin (1914) have called attention to the fallacy of basing conclusions as to origin on the wounds found on a canker, since these are quite as likely to have followed as to have preceded the entrance of the parasite. These experimenters made a large number of inoculations in various kinds of wounds, imitating the wounds that are found naturally on the trees. Their results are given in Tables 1 and 2:

TABLE 1. COMPARATIVE VALUE OF DIFFERENT KINDS OF WOUNDS FOR INFECTION. CHARTER OAK, PENNSYLVANIA

Character of wound	Inoculum	Number of inoculations	Percentage successful
Longitudinal slit	Diseased bark	568	93.6
Longitudinal slit	Mycelium from culture	454	89.2
Diagonal slit	Mycelium from culture	25	96.0
Diagonal slit	Dry spore horns	16	93.7
V-shaped cuts	Conidia in water	97	93.8
V-shaped cuts	Ascospores in water	88	94.3
V-shaped cuts	Ascospores shot in dry	1,228	82.5
Artificial borer holes	Mycelium from culture	68	54.4
Natural insect holes	Mycelium from culture	18	0.0
Natural insect holes	Conidia in water	23	0.0
Natural insect holes	Ascospores in water	22	0.0
Peeling down bark	Mycelium from culture	25	88.0
Stab with knife	Ascospores in water	347	36.9
Stab with knife	Conidia in water	81	86.8
Stab with knife	Dry spore horns	96	79.1
Scraping off outer cork layer	Mycelium from culture	25	0.0
Cut stubs	Mycelium from culture	22	81.8
Broken branches	Mycelium from culture	45	71.9
Natural cracks	Mycelium from culture	25	0.0
Gimlet holes	Ascospores in water	135	52.6
Hypodermic needle	Ascospores in water	54	75.9

TABLE 2. RESULTS OF INOCULATIONS MADE IN WOUNDS FROM MAY 1 TO SEPTEMBER 1, 1913, AT NAPANOCH, NEW YORK

Method	Inoculum	Number made	Number infected	Percentage of infection	Average percentage of infection
Slits in bark	Ascospores in water	89	88	99	92
	Conidia in water	116	95	82	
	Mycelium from culture	61	61	100	
	Diseased bark	93	93	100	
	Conidia dry	10	10	100	
	Pycnidia from wood	11	4	36	
Injections	Ascospores	107	74	69	74
	Conidia	56	46	82	
Saw wounds	Diseased bark	50	26	52	52

As to the nature of the wound necessary for infection, they conclude that any kind of wound in the bark deeper that the outer green cortex may furnish an entrance.

The fact that a large proportion of incipient cankers occur about dead twigs, or small branches, has suggested that the pathogen gains entrance to the living tissue through the dead tissue of such branches. But it is usually impossible to tell whether the dying of the twig preceded the entrance of the fungus, or whether the twig died as a result of the canker having been formed about it. Other reasons could be assigned as explaining the above condition. The rough bark around the insertion of small branches remains moist longer than does smooth bark, and thus furnishes more favorable conditions for spore germination. Insect injuries are more numerous at such places and also the bark often becomes cracked above the insertion, thus offering more opportunities of entrance to the parasite.

Age of tree and parts of host affected.— After the first year the age and the size of the tree make no difference in its susceptibility. Not only may cankers be found in the woods just as often on trees an inch in diameter as on those two feet in diameter, but also inoculations on large trees produce the disease just as surely as do those on small trees. Also, there is no difference in susceptibility between the trunks and the branches of any size. Inoculations produce the disease equally well on all.

All inoculations of green leaves have failed. Murrill (1906 a) was unable to produce the disease on green shoots of the first year. Metcalf and Collins also state that green twigs are not affected. Metcalf (1913:365) states: " Late in the season it will readily attack wood of the current year." Anderson and Babcock (1913), however, successfully inoculated first-year green shoots both with ascospores and by inserting diseased bark; Rankin (1914) also produced the disease on first-year shoots by inoculation with ascospores at Napanoch, New York. Yet it is readily apparent that green shoots are less often attacked than are older ones; also the percentage of infection is higher during the latter part of the growing season than during the early summer. All inoculations made by the writers on green burs have failed.

Metcalf and Collins (1910) state that roots are rarely, if ever, attacked, but the pustules of the fungus are commonly found on exposed roots; Anderson and Babcock (1913) were able to grow the fungus on subterranean roots, also, but no typical cankers were produced. It is certain that the roots are not killed by the fungus, because they seem not to lose their power of producing new shoots even when the part of the tree above ground is entirely killed by the parasite.

The orientation of lesions on the trees shows no relation to the points of the compass. Data compiled for nearly a thousand trees taken at

random in New York and Pennsylvania showed no preponderance of cankers on any particular side of the trees. (Anderson and Babcock [1913] and Rankin [1914]).

Effect of season.— Beginning with June, 1912, inoculations were made at Charter Oak, Pennsylvania, in every month of the year. Twenty-five or more inoculations were made each time, with each of the following inocula: (1) ascospores, (2) pycnospores, (3) agar containing mycelium, (4) diseased bark. The spores were inoculated by making a suspension of them in water and inserting a few drops into a stab made with a knife in the bark; the other inocula were inserted into a small slit in the bark. In Table 3 are shown the results for the year, the plus sign meaning that infection resulted and the minus sign meaning that it failed. Where the results are marked positive, over fifty per cent of

TABLE 3. RESULTS OF MONTHLY INOCULATIONS

Inoculum	June	July	August	September	October	November	December	January	February	March	April	May
Ascospores	+	+	+	+	—	—	—	—	—	—	+	+
Pycnospores	+	+	+	+	—	—	—	—	—	—	+	+
Mycelium in culture	+	+	+	+	—	—	—	+	—	—	+	+
Diseased bark	+	+	+	+	+	+	+	+	+	+	+	+

the inoculations produced cankers in every case except in the January inoculations with mycelium, of which only a very small percentage were successful. A similar set of experiments at Napanoch, New York, gave like results. The results indicate that infection from spores does not occur during the six months from October to March, inclusive. Apparently, then, even if spores should gain access to wounds during the winter, infection would not necessarily result. Very little difference between the percentage of cankers produced was noticed during the remaining months of the year.

Development of the canker

If the inoculum is diseased bark or agar containing mycelium, the canker usually begins to show externally in about two weeks after inoculation in summer. If either kind of spores are used, the canker does not show until after three to five weeks. A longer time is required in the cool months of spring and autumn. The canker appears first as a darker area about the point of inoculation. In dry periods this affected part soon sinks and at the same time the bark takes on a reddish color. In

this case the limits of the canker are easily distinguished on the surface; in rainy seasons the outline at first is not sharp, but if the canker is cut into with a knife a sharp line of demarcation will be found between the brown, diseased bark and the white, healthy, inner bark.

When the spores have germinated in a wound, the germ tube thrives on the injured and dead cells until it has produced a mass of mycelium. Then, gradually accumulating strength as it increases, the mycelium *en masse* pushes out into the living tissue of the bark. Single threads do not seem to possess the power of penetrating alone among the living cells, but the invasion is accomplished by the force of mass action. Starting from a narrow point, the hyphæ grow out in ray-like bundles, completely destroying parenchyma and collenchyma and cambium cells as they go. The rôle of toxins or enzymes in this process has not been investigated. All the rays starting from a single point are contiguous, forming the fan-like mats previously mentioned.

Rate of growth of mycelium.— The rate of growth of mycelium under natural conditions in the tree can be roughly measured by the increase in size of the cankers. The growth varies with the temperature, being the most rapid during the summer months; but the mycelium does not always remain dormant during the winter, as will be shown. For twelve consecutive months at Charter Oak, Pennsylvania, cankers were outlined with a painted white line at the end of each month and the average rate of growth was computed. A second experiment of a similar nature was conducted at Napanoch, New York. The data on these two experiments are given in Tables 4 and 5. These tables give only the rate of growth

TABLE 4. MONTHLY RATE OF GROWTH IN DIAMETER OF CANKERS AT CHARTER OAK, PENNSYLVANIA

Month	Number of cankers	Average growth per month (in centimeters)
1912		
June	31	1.88
July	200	2.78
August	186	2.83
September	140	1.85
October	53	1.92
November	27	0.00
December	27	——
1913		
January	89	0.51
February	89	0.00
March	84	0.7
April	21	1.1
May	41	2.4

TABLE 5. AVERAGE RATE OF GROWTH OF CANKERS DURING SUMMER MONTHS, AT NAPANOCH, NEW YORK

Date when inoculations were made	Number of inoculations	Growth by periods of four weeks (in centimeters)				
		May	June	July	August	September
May 2	60	1.35	1.75	3.0	2.4	2.3
June 1	48		2.5	1.72	3.0	...
June 11	16			2.0	1.9	...
July 3	41			1.75	...	...
July 11	105			2.0	1.7	1.7
August 1	11				2.1	...
Average	..	1.35	2.08	2.1	2.2	1.9

of the canker around the tree, the increase in length being considered not so important. It appears that the mycelium continues to grow even during mild periods of the winter, such as were frequent during January of 1913.

As a check on the above data, agar plate cultures were kept out during the winter and growth was recorded during each warm period. In this connection, Shear and Stevens (1913 a:9) note that the minimum temperature for growth of the fungus in culture is 9° C. (48° F.), which temperature was exceeded on ten different days during January.

Even the most rapid growth, as recorded above for the summer months, is less than one millimeter a day. But on artificial media a growth of three millimeters a day is not unusual. Mycelium also spreads at a much more rapid rate in the dying bark after a tree is cut.

Vitality of mycelium.— The mycelium does not seem to be injured in the least by freezing. It remains alive in all parts of the canker during the winter. Cultures were kept frozen for a month at a time, and resumed growth naturally on being brought back into the laboratory. The mycelium is not readily killed by desiccation. Bark removed from a canker and kept perfectly dry in the laboratory for ten months yielded quite as successful isolations as did fresh bark. Chips of diseased bark left on the ground in the woods were found to contain living mycelium one year later. This remarkable vitality of the mycelium is one of the factors that make the disease difficult to control.

Development of pycnidium.— The pycnidial stage usually appears on the cankers in three to six weeks after inoculation. The very earliest stages in the development of the pycnidium are not readily found and studied in the bark, but when the fungus is grown in Van Tieghem cells in drops of agar the process can be easily observed under the microscope. At room temperature it begins in less than a week, in the following manner:

At a certain point on a hypha, short cells are formed by the laying down of new septa. These cells increase in diameter and in amount of contents and each one sends out short septate branches (Fig. 92, a and b).

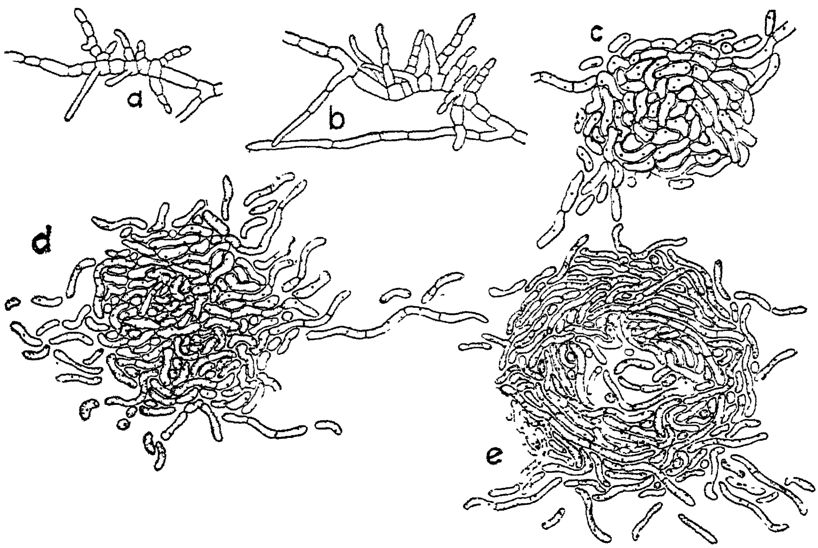

FIG. 92.— *Development of pycnidium*

a and b, Very earliest stages observed in Van Tieghem cell cultures
c and d, Cross sections of pycnidium on agar before the beginning of the cavity
e, Cross section when the cavity first becomes apparent

the individual cells of which in turn put out other short branches, until the whole structure has the appearance of a witches' broom. Other hyphæ, and more distant branches of the same hypha, grow toward it and mingle with its branches. This tangle of hyphæ soon becomes so dense that a surface view does not show what is occurring on the inside, and later stages have to be studied from serial sections after imbedding, sectioning, and staining. Cross sections at this time and for some days later show that the mass is merely an increasing solid ball of hyphæ, which are all alike and densely interwoven but not anastomosed in any way (Fig. 92, c and d). A little later the hyphæ at the center appear

looser (Fig. 92, e) and those branches that extend into this loose central area begin to cut off regular cells (pycnospores) from their apices. More branches (conidiophores) now grow in and cut off spores from their apices, until the wall, which constantly recedes as the pycnidium becomes larger, is completely lined with the brush-like hymenium (Fig. 86, page 559) and the cavity is packed with spores. Meanwhile an ostiole is formed by the loosening of the hyphæ at the apex, and the spores are forced out through it in a gelatinous mass. The cells of the loose wall seem never to divide meristematically, and the wall in this type never appears pseudoparenchymatous.

The first outward indication of the formation of pycnidia on the young canker is the appearance of numerous small, raised, smooth blisters just back of the advancing edge of the lesion (Plate XXXVIII, Fig. 1). They show no relation to the lenticels. Under each blister is the beginning of a single pycnidium. At this stage the pycnidia are more or less globose cushions with a moist, gelatinous appearance; about half of the pycnidium is imbedded in the disintegrating collenchyma tissue, the other half projects upward and raises the cork layer to form the pimple. There is no stroma at this time, but each pycnidium is early surrounded with a fringe of loose mycelium which is the forerunner of a stroma. A cross section of this hygrophanous cushion shows it to be a closely wound ball of hyphæ corresponding to the stage represented in Fig. 92, c and d. It increases in size and develops into a mature pycnidium just as the process on agar was described above, pushing up the cork layer and finally causing it to rupture at the tip, from which point the spores are forced out. Meanwhile the stroma is forming about the pycnidium. So far as observed, the stroma never precedes, but always follows, the early stages in the development of the pycnidium. With the active increase in the amount of stromatic tissue which is constantly added from below, the pycnidia are pushed out in the top of the stroma through the cork layer. Meanwhile they continue to increase in size and become irregular in shape. (Fig. 84, page 558, and Plate XL, Fig. 1). Often the entire stroma is found honeycombed with numerous communicating lobulated chambers.

Time of production of pycnospores.— In Pennsylvania during the seasons of 1912 and 1913 the spore horns first began to appear on the cankers about the middle of April; after that they could be found at any time during the summer, being especially abundant after periods of rain. During the season of 1912, on cankers produced by inoculation in the spring, the tendrils were abundant after each rain period until the latter part of the summer, when the perithecial stage began to develop; after that, few spore horns were found on the cankers. Heald and Gardner (1913 a) state that pycnospores are produced in enormous numbers during

the winter months. Fresh spore horns are not seen during the winter, but this may be due to the fact that they are produced at such a slow rate that they are washed away before their size makes them noticeable.

Development of perithecium.— The beginning of the perithecial stage is accompanied by a marked increase in the size of the stroma, which now pushes off more of the cork layer and not only fills up the enlarged rent but also grows out over the torn edges so that they are included in it (Fig. 85, page 558). The stroma takes on an erumpent, superficial appearance (Plate XXXVII). This change has been observed within eight weeks after inoculation; on trees inoculated in June the stromata have been found in August.

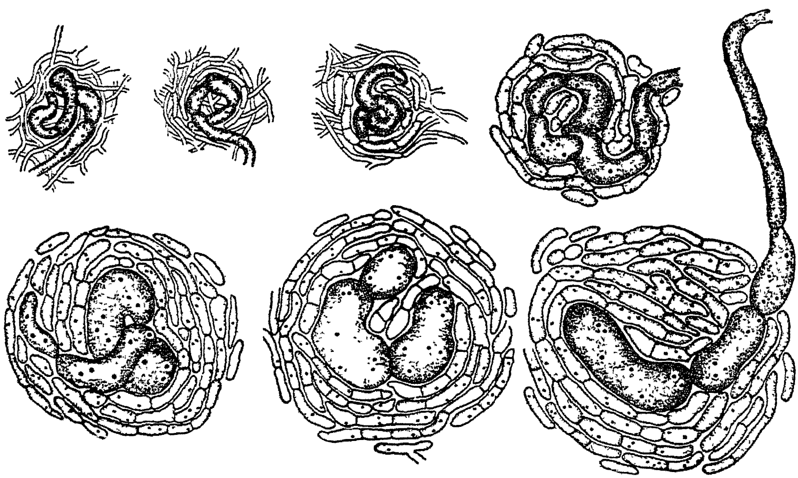

FIG. 93.— *Stages in the development of the carpogonium. The larger, heavily shaded cells at the center are the ascogonial cells, with the cells of the enveloping hyphæ about them. The last figure shows the continuation of the ascogonium into the trichogyne. All figures are drawn to the same scale*

The primordia — beginnings of the perithecia — arise in the base of the stroma or even among the outermost cells of the host. Each primordium consists of two to five large, prominent cells arranged in a circle or a spiral (Fig. 93), closely invested by a sheath of large hyphæ. The central prominent cells form the ascogonium, and the investing hyphæ will here be called the envelope. The ascogonium, which is an enlarged single hypha, is continued up to the surface of the stroma as a prominent thread, the trichogyne. There may be as many as a hundred primordia in a single stroma, but only about one fourth of them ever reach maturity; the others degenerate at various stages of development.

The ascogonial cells are elongated-oval, slightly curved so as to fit the segment of the spiral, deeply constricted at the septa, and only loosely

connected. They are filled with dense protoplasm and contain more numerous and more prominent nuclei than do the cells of the envelope. The cells of the trichogyne resemble those of the ascogonium in every way except that they are narrower and are not curved nor so loosely connected. The trichogyne is apparently a useless organ in the formation of the perithecium. During the development of the latter it degenerates and disappears.

The highest stage in the development of the ascogonium is shown in Fig. 93. From this time on it begins to degenerate. The dense protoplasmic content gradually becomes thinner, and later there are only ragged bridles of protoplasm across the lumen and irregular masses around the walls (Fig. 94) or else the entire contents draw up into a misshapen mass. But the behavior of the enveloping cells is quite the contrary. Their contents now become more dense, and their nuclei more prominent and apparently more numerous. Up to this time the individual hyphæ can be traced and open spaces are apparent between them; but now they have increased both in size and in number and have filled up the intervening spaces. They appear as a pseudoparenchymatous tissue instead of as a coil of hyphæ.

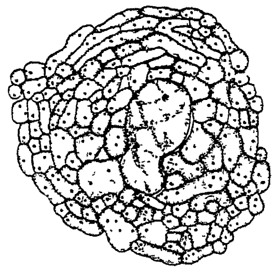

FIG. 94.— *Cross section of the developing perithecium just as the ascogonial cells (one large one shown at the center) are beginning to degenerate and the enveloping hyphæ are taking on a pseudoparenchymatous appearance*

Before degeneration the ascogonia probably give rise to ascogenous hyphæ, but these are very quickly cut off by septa and are indistinguishable among the enveloping hyphæ. The ascogonial cells are soon crowded out of shape by the growth of the enveloping cells, and in later stages they appear only as misshapen masses wedged between the other cells. The whole primordium now increases rapidly in size and takes on the appearance shown in Fig. 95. The beginning of the neck is shown at the top of the figure. Next, the wall is differentiated from the large-celled core. A cavity is formed by the breaking-down of some of the core cells, but is soon almost filled by paraphyses which arise from the bottom of the cavity (Fig. 88, a, page 561). The young asci grow up between the paraphyses, arising from a system of hyphæ which are presumably the continuation of the branches of the ascogonial cells. Eight bicellular spores are formed in each of the clavate asci. The hyphæ that initiated the formation of the neck now push toward the surface, leaving a canal through the center (Fig. 88, b). Branches of these hyphæ extend into the canal to form the periphyses (Fig. 88, c). Meanwhile the cavity

has become completely filled with maturing asci and the perithecium is now ready to discharge its spores.

Time of development of perithecia.— On cankers produced by inoculation during spring and summer, mature perithecia are developed in early autumn. It is evident, however, that this is not the only season at which they may be produced, because there is no time of the year at which they cannot be found in abundance, ready to eject spores if the proper conditions of moisture and temperature are supplied.

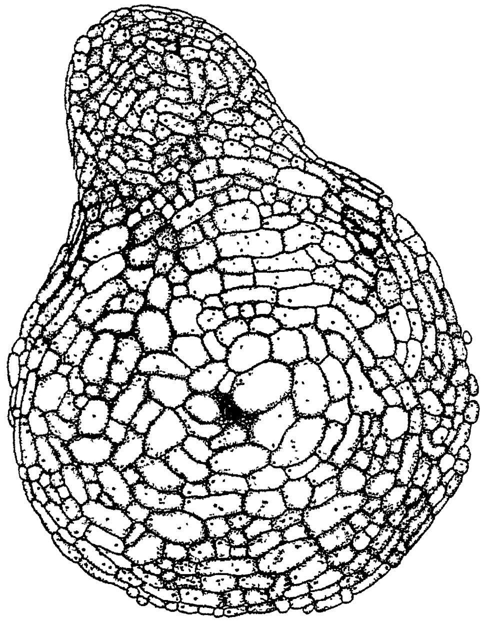

FIG. 95.— *Cross section of the young perithecium before the differentiation of the wall and the core cells, showing at the center the shriveled remains of an ascogonial cell and at the top the beginning of the neck*

Ejection of ascospores

One of the writers of this bulletin (Rankin, 1912 a) discovered that during rain periods the ascospores are ejected with some force into the air from the ostioles of the perithecia. The asci, which usually fill the perithecium, are pushed up through the neck when abundant free water is added to the stroma. This expulsion of the asci is largely due to the swelling pressure of the asci. A dry ascus with its spores (Fig. 89, b, page 562) occupies only about one half the space occupied by an ascus after water is added (Fig. 89, c and d).

Prepared sections of perithecia fixed during the process of ejection of spores show that the spores remain in the asci almost to the tip of the neck. Since the asci themselves are never ejected into the air, it follows that they must burst and liberate the spores when they arrive at the surface of the film of water. The ejection may be observed with a hand lens. The only visible phenomenon is the sudden and regular breaking of the film over the ostiole. This gives for the moment the impression of a point of light. The entire contents of the ascus are ejected at once into the air.

Rankin (1914) has drawn the following conclusions as to the process of the actual ejection of the spores from the asci: The imbibition of water results in the asci being forced out through the ostiole, where,

if a film of water is present, the walls begin to gelatinize. Undoubtedly, as more and more asci are pushed out, some arise in the water to the surface and may even project above the surface, due to the disturbance. It might be expected, then, that the increased pressure on the ascus wall due to the swelling of the contents, at a time when the wall is gelatinizing, will result in the sudden rupture of the wall when the ascus arises to or above the surface of the water. Since the lower part of the ascus wall is the thinner and gelatinizes first, freeing the spores, and since no change suggesting pore or other type of apical dehiscence has been found, it is presumed that what proves to be a successful method of ejection is due merely to a combination of physical factors, not to any structural arrangements.

Saprophytic growth

Endothia parasitica may live indefinitely as a saprophyte. In this condition it is not so restricted in its feeding habits as is the case otherwise. Where it is found growing on trees outside the genus Castanea, it usually exists there only as a saprophyte. It may be grown in pure culture on sterilized twigs of almost any of the common forest trees. It has also been grown on a wide range of culture media. Anderson and Babcock (1913) report cases in which trees with scattered cankers were cut and were left lying on the ground during the summer; in the autumn the fungus was found to cover the entire trunk. Also, they found that the fungus spreads rapidly in fire-killed bark. When it grows in dead bark, no canker-like area is formed, and also the mycelium does not progress by the production of fan-like mats but by single threads. The fungus spreads through dead bark many times more rapidly than through living tissue. Anderson and Babcock made successful inoculations on dead bark with ascospores and with mycelium, and on dead leaves and dead burs with ascospores. The fungus grew and produced pycnidia on all of these. Collins (1913) also found the fungus growing saprophytically on burs. Apparently its growth is checked only by failure of the moisture supply.

In order to determine how long the mycelium lives on logs after they have been cut, both with the bark on and with it removed, and also on the stumps from which the logs are cut, and whether the fruiting stages are produced under these conditions, the following experiment was performed: Thirty-two trees, some entirely dead and some still living, were felled, cut into seven-foot logs, and allowed to remain lying on the ground. Some were peeled, others were left with the bark attached. Also some of the stumps were peeled. Isolations were made from the interior of the bark and the wood — care being taken to avoid getting any spores of the fungus in the cultures — during each month for one

year. In Table 6 are shown the results of the last set of isolations, at the end of one year; the table shows how well the fungus may maintain itself as a saprophyte. Pycnidia were formed in countless numbers on the peeled logs and on the cut ends of the stumps and the logs. Stromata and perithecia developed on some of the unpeeled logs, but none developed on the peeled logs. The writers have on several occasions isolated the fungus from woodpiles. rustic woodwork, and the like, where the trees were said to have been cut several years previously.

TABLE 6. RESULTS OF ISOLATIONS FROM LOGS AND STUMPS ONE YEAR AFTER TREES WERE CUT

Trees dead when cut	Number containing live mycelium
15 logs, peeled	11 logs
58 logs, not peeled	46 logs
4 stumps, peeled	4 stumps
13 stumps, not peeled	11 stumps
Trees alive when cut	
3 logs, peeled	1 log
38 logs, not peeled	32 logs
1 stump, peeled	1 stump
9 stumps, not peeled	8 stumps

Where the moisture conditions are favorable, the fungus is often found growing luxuriantly in the bottom of piles of chips where diseased trees have been cut. It has also been proved, by inoculation with conidia, that the fungus will grow and produce pycnidia even on humus such as is found about the base of the trees.

Dissemination

That this fungus spreads with astonishing rapidity is a matter of common observation. Not only does it spread quickly from one tree to those standing close about it, but it is remarkable for its long jumps across country. It suddenly appears in a neighborhood far ahead of the main line of advance, without there being another diseased tree for a distance of many miles. Hundreds of these isolated spot infections have come to notice and have given rise to much speculation as to their origin. After the disease has once appeared in a locality it is usually a matter of only a few years until the neighborhood for miles around is thoroughly infested. What agents are responsible for carrying the causal organism from one tree to another, and thus causing this rapid spread? Many answers have been suggested, but unfortunately most of them have been mere conjectures not based on experimental data.

Most of the early writers confined their attention to the pycnospores, and it has only been within the last few years that attention has been called to the fact that the ascospores also are instrumental in the spread of the fungus. Murrill (1906 a) suggests the agency of wind, squirrels, birds, insects, mice, moles, and rabbits, and later (1906 b) rain — the last only carrying the spores from one part of a tree to other parts. Hodson (1908: 5) says, in regard to the dissemination of the pycnospores:

"Wind is probably the principal agency, but the spores are no doubt carried by animals, birds, insects and by shipment of infected material.

"The disease spreads locally through the gradual distribution of the spores from tree to tree, and at a distance chiefly through the shipment of infected material, such as nursery stock, bark, nuts, and other products. There is a possibility that long-distance infection is also effected by means of migratory birds."

Metcalf and Collins (1911: 9) state: "As both kinds of spores appear to be sticky, there is no evidence that they are transmitted by wind except where they may be washed down into the dust and so blown about with the dust. The spores are spread easily through short distances by rain; particularly they are washed down from twig infections to the lower parts of the tree. There is strong evidence that the spores are spread extensively by birds, especially woodpeckers, and there is also excellent evidence that they are spread by insects and by various rodents, such as squirrels. The disease is carried bodily for considerable distances in tan bark and unbarked timber derived from diseased trees. One of the most prolific sources of general infection has been the transportation of diseased chestnut nursery stock from infected to uninfected localities."

One of the writers of this bulletin (Rankin, 1912, a and b) called attention to the fact that the ascospores are forcibly ejected into the air, and that these can be caught up by the wind and carried for considerable distances and may well be responsible for a large part of the infection. Fulton (1912: 51) reports experiments in which he tried to dislodge spore horns by a strong blast from an electric fan. He found that bits of the spore horns were sometimes broken off and carried for short distances, but were too heavy to be carried for great distances.

Anderson and Babcock (1913) have considered the problem of dissemination more in detail than have the other writers. Unless otherwise mentioned, the matter considered below is taken from their bulletin.

Man

Murrill (1908 a) was the first to call attention to the danger of spreading the disease into new localities on diseased nursery stock. Metcalf and Collins (1909: 49) gave especial attention to this phase of the matter,

and believe that it is largely responsible for the long-distance jumps of the disease. They state:

"It becomes more and more evident as this disease is studied that diseased nursery stock is the most important factor in its spread to distant points. In that part of the country where it is already well established in the native chestnuts its progress is rapid and sure, but there is no evidence at present that it is able to pass to remote districts, tens or hundreds of miles away, except on diseased nursery stock. Of course it is conceivable that the spores are carried by birds. Such distribution would, however, follow in general the great lines of bird migration north and south and hence would not be an important factor in the western spread, except locally. During the summer of 1908 nearly every chestnut nursery and orchard of importance in the Atlantic States north of North Carolina was visited, and very few were found free from the bark disease. Several cases were observed where the disease had obviously spread from the nursery to adjacent wild trees."

Five prominent cases of spot infections far ahead of the main line of advance in western Pennsylvania were traced to nursery trees or scions shipped there from infested territory.

In order to see whether the fungus could be carried on tools that were first used on diseased trees and then on healthy ones, thirteen cuts were made on healthy trees with an axe after having chopped into diseased logs with this ax. Cankers developed later about twelve of these. One of the writers performed an experiment of a similar nature, in which a saw was first used in sawing diseased wood and then in sawing off healthy branches. Cankers were developed about twenty-seven of the fifty stubs treated in this way. There is no doubt, then, that the disease may be spread by pruning saws, axes, climbers, and other tools used about the trees.

Metcalf (1913) and others have also suggested the possibility of the fungus being carried for long distances by the shipping of ties, poles, tanbark, and the like. The experiments previously described in treating of saprophytic growth show the remarkable ability of the fungus to maintain and propagate itself under saprophytic conditions. The writers of this bulletin also found that perithecia retain their ability to eject spores for at least seven months under perfectly dry conditions. There is no reason why the disease cannot start in a new locality to which affected logs are shipped, if in that locality the logs are placed near growing chestnut trees. It must be admitted, however, that no case of outbreak of the disease in a new locality has ever been traced to the shipment of such material.

Insects

Insects are found in great numbers both in and on chestnut bark, and the possibility that they may crawl over sticky spore horns and carry spores away to deposit them in wounds, and thus start new cankers, has occurred to the majority of writers who have mentioned dissemination. It is reasonable to believe that many infections do occur in this way, but the mere statement of the probability without experimental data is not convincing; and unfortunately such data are meager in the literature.

In order to prove that an insect — or anything else, for that matter — is a direct agent of dissemination, three points must be demonstrated: (1) that the insect is in the habit of visiting cankers and actually carrying away spores on its body; (2) that it deposits these spores in wounds favorable for germination; (3) that infections do result from wounds inoculated in this way. To induce insects to crawl over damp spore horns or active perithecia and then demonstrate the presence of spores on their bodies, is no proof that they are in nature responsible for the spread of the disease. Ruggles (Penn. Chestnut Tree Blight Com., 1914) has shown the fallacy of this argument. After allowing ants and about twenty other species of insects to run over spore horns and active perithecia, he was able to isolate spores of Endothia from all of them. Yet he proved to his own satisfaction that ants are not responsible for infection. The following is from the summary of his work in Bulletin 9 of the Pennsylvania Chestnut Tree Blight Commission: "Two rooms were set off in an insectary. The inner of these two rooms being thoroughly sterilized was called the sterile room, the outer room was called the blighted room. In the latter as much blight material as could be obtained of the kind required was kept and placed on the ant table, where three colonies of ants made their homes. From the table in this room the ants were allowed to run through a glass tube to sterile seedlings in the sterile room. . . . The result of the experiment was that with the exception of a few dried leaves on each tree which were chewed or worked on by the ants, the trees in the sterile room are as healthy as when first placed on the table to be run over by the ants. The indication, therefore, is that ants are not responsible for blight infection."

Studhalter (1914) also reports the presence of spores on the bodies of twenty-four out of seventy-five insects after they had run over cankers or had been taken directly from diseased trees in the field.

Indirectly, insects may be connected with the spread of the disease by making wounds in the bark where spores may gain entrance after having been carried by some other agent. Anderson and Babcock (1913) and Ruggles (Penn. Chestnut Tree Blight Com., 1914) are of the opinion that this is the most serious way in which insects are related to blight

dissemination. Ruggles states that in some places in eastern Pennsylvania, 86 to 93.8 per cent of all infections were in wounds produced by the seventeen-year cicada. The bast-miner larvæ, which are present in great numbers on smooth-bark trees, have often been said to be responsible in this way. Ruggles states that fifty per cent of the infections in smooth-bark trees originated in the exit holes of these insects. He also suggests their responsibility for the numerous crotch infections, since they oviposit near crotches. Anderson and Babcock, on the other hand, were unable to produce infection by making inoculations in exit holes of these insects.

The pustules of the fungus are often eaten by some insects, the most common of these being *Leptostylus maculata;* but experiments have proved that the spores, after being eaten, are digested and do not serve to spread the disease. Craighead (1912) reports five different species of insects which he found eating the pustules, but believes that they contribute to the control of the disease rather than to its spread. The United States Bureau of Entomology has made much of these discoveries and has suggested that these beneficial insects may be a large factor in the final control of the disease (Pennsylvania Chestnut Tree Blight Commission, 1914). Ruggles, however, shows that the insect mentioned above, *Leptostylus maculata*, carries enormous numbers of spores on its body, and suggests that it is more injurious as a disseminator of spores than beneficial as a destroyer.

Metcalf and Collins (1911) state that in many parts of the country the two-lined chestnut-borer (*Agrilus bilineatus*) is directly associated with ninety per cent of all cases of the disease. It was to the so-called bast-miner, however, that they referred, rather than to the borer mentioned (Ruggles, 1913).

Davis (Penn. Chestnut Tree Blight Com., 1913:48) attributes to ants seventy-five to ninety per cent of the cases of infection in the locality where he was working. The grounds for the statement are the fact that no summer nor winter spores could be found and yet the disease continued to spread, and also the fact that ants were found carrying mycelial threads of the fungus. The anomalous condition of trees in an affected area not producing any spores, and Davis' proof that the mycelium carried by the ants was really that of *Endothia parasitica* and that it was deposited in wounds favorable for infection, require further explanation.

Rain

Rain dissolves the mucilaginous matrix of the spore horns, and the pycnospores are washed down the trunks where they lodge in wounds and produce cankers. They may also be splashed to other trees that are in close proximity to diseased ones. This accounts for the fact that

most trees with cankers above are also diseased about the base. Also, ascospores, which sometimes ooze out instead of being forcibly ejected, may be carried down in this manner. It was proved by a large number of inoculation experiments that either ascospores or pycnospores suspended in water in this manner and introduced into wounds will produce a high percentage of cankers (Tables 1 and 2, page 571).

In another set of experiments, wounds were made beneath cankers on which there were only spore horns. The cankers were sprayed with an atomizer and the water containing the spores was allowed to run down into the wounds. Of twenty-three wounds treated in this way, sixteen developed cankers later. There is no doubt, then, that rain is an important agent in spreading the spores to different parts of the same tree. Rain also plays an important part in bringing about the conditions necessary for the ejection of ascospores.

Birds

It seems reasonable to believe that birds alighting on cankers and picking at them carry spores to other trees and deposit them in wounds where they may germinate and produce cankers. Anderson and Babcock (1913) shot birds during the summer, but no spores could be isolated from them. Heald and Studhalter (1913) tested the washings from thirty-six birds of nine different species, all of which were shot on diseased parts of trees between February and May. Downy woodpeckers, nuthatches, golden-crowned kinglets, sapsuckers, brown creepers, and juncos were found to carry enormous numbers of pycnospores, the smallest number per bird being 5655 and the largest 757,074. No ascospores were found on the birds.

There can be little doubt that birds aid in the dissemination of the fungus.

Wind

Unlike the agents mentioned heretofore, the wind as a disseminator has to do mostly with ascospores. In a number of the earlier contributions to the literature it is stated that the summer spores are blown about by the wind; but this belief was gradually abandoned when it was pointed out that the spore horns are so hard when dry that they cannot be broken even by a strong blast, and when wet they are of a sticky nature and can hardly be detached by the wind. Metcalf (1913:366), however, still believes that under certain conditions they may be carried by the wind, for he says:

"It is conceivable that they may be blown by the wind as far as rain or spray is blown or, mingling with the dust at the foot of the tree, be blown about with the dust."

Experimental data are not cited.

The writers performed experiments in order to determine the conditions necessary for ejection, rate of ejection, spore content of the air, ability of wind-blown spores to produce infection, and the like.

Ascospores are not peculiarly winter spores, but they may be found maturing and ready for ejection at any time of the year. Experiments by Heald and Gardner (1913 a), however, indicate that they are not ejected during the winter. These experimenters found that after the stromata were subjected to low temperatures they did not resume ejection of ascospores again for three or four days after being brought into favorable temperatures, and that the minimum temperature for spore ejection varies from 52° to 60° F. Experiments show that during the summer spores are ejected only during and shortly after rains — in fact, just as long as the bark remains wet. This may be a half hour or it may be more than a day. The same stroma may resume expulsion any number of times during the summer. Alternating periods of abundance of moisture and desiccation were not found to interfere with the ability to eject spores. In case the bark remains wet continuously, it was found that a single stroma would continue uninterrupted ejection for twenty-six days. One case is reported in Bulletin 9 of the Pennsylvania Chestnut Tree Blight Commission, in which bark containing ascospore pustules continued to expel ascospores for over six months (in the laboratory). The rate of ejection from a single ostiole was determined to be one ejection for each two seconds, that is, about four spores a second. This would be 14,400 spores an hour from a single perithecium. The maximum height of ejection found was twenty-two millimeters. Horizontally, from a stroma two centimeters above an agar plate, spores were ejected to a distance of eighty-nine millimeters on the plate, the experiment being performed under a bell jar.

The spore content of the air was determined by two methods. The first was the usual aspirator method used in quantitative analysis for bacteria. By this method no spores could be found in the air during dry weather, but when the air within a few feet of wet cankers was tested there was an average of four and three tenths spores per liter. The second method was the exposure of sterile agar plates at varying distances from moist cankers. When these plates were exposed for a short time close under a canker, as many as 9000 spores were caught on one plate, but the number decreased as the distance between the canker and the plates was increased. Spores were easily secured at a distance of fifty-one feet with a moderate wind blowing from the diseased bark toward the plates on a level with it. No greater distances were tried; but if spores can be so easily caught at that distance on a ten-centimeter plate in a moderate wind on a level

place, one can well imagine their being blown for miles in a strong wind from tall trees and from the tops of the mountain ridges where the disease is frequently found. Heald, Gardner, and Studhalter (1914) were able to catch the spores over three hundred and eighty feet from the nearest tree.

Having proved that the spores are ejected all through the summer and that they are carried about in great numbers by the wind, only one link of a solid chain of evidence was missing: that was to prove that such wind-blown spores produce cankers when they fall into wounds. In the first series of experiments in order to determine this point, bark containing active perithecia was supported within a few inches of sterile wounds in healthy trees for a short time and then the wounds were wrapped with cotton in order to exclude later inoculation. Of the 1395 wounds treated in this way, seventy-eight per cent developed cankers. In the next set of experiments, the distance was increased to one to four feet and a wind was artificially produced by bellows. Seventy-four per cent of the 185 wounds treated in this way had cankers about them later. Wounds treated in the same way but not exposed to shooting perithecia remained uninfected.

In another experiment, groups of trees were selected in which some had cankers on them while others were free from disease. Sterile wounds were made in the healthy trees and protected by fine-meshed wire screen and cotton bands, so that it was believed that spores could not be introduced in any way except by the wind. The cankers on the diseased trees were frequently drenched in order to induce spore ejection. Of the 559 wounds treated in this way, 114 developed cankers.

The results of the above experiments lead the writers to believe that wind is an important factor in the spread of the disease.

Other animate agents

It is easy to believe that the sticky pycnospores remain attached to the feet of animals, such as squirrels, mice, and numerous others which run over the cankers. But after the spores are isolated from them, as undoubtedly they could be, it would still be necessary to prove that such spores are deposited in wounds where they produce infection. Statements made with respect to the agency of animals in dissemination should be supported by more complete chains of experimental data than have been commonly adduced.

It can be said at present only that it is possible that the fungus is spread by such means.

PATHOLOGICAL HISTOLOGY

Keefer (1914) reports detailed microchemic and histologic studies of the effect of the fungus in the bark and the wood of the tree. He

finds that the outer and internal cork layers, sclerenchyma (bast fibers and stone cells), and crystal-containing cells are not in any way affected. All tissues composed of cells having more or less pure cellulose cell walls are destroyed (except medullary rays). The collenchyma and the thin-walled parenchyma of the primary cortex, the parenchyma of the pericycle, the sieve tubes and the phloem parenchyma of the bast zone, and the fascicular cambium, are enumerated as the tissues that are in most cases wholly destroyed and replaced by the fans of mycelium. It was found that cellulose cell walls became partially lignified in proximity to the advancing edge of the mycelium fan. The degree of lignification, however, is not sufficient to furnish immunity of the tissues to the action of the fungus, as seems to be the case with the more completely lignified tissues, such as the sclerenchyma. The cells of the medullary rays in the bast zone are partially lignified, but the cells are not individually affected or broken. There is an increase in the number of medullary ray cells, due probably to a stimulating action by the fungus. The original cells divide and redivide until great masses of new cells are formed, so that there is a crowding of the phloem tissues and a radial and tangential separating of the segments of the bast zones. This is the histologic change, evidently, which accounts for the slight, and at times pronounced, hypertrophy of the cankered area. The destruction of the various tissues of the bark is explained on the basis that the cells are broken and destroyed by the mechanical action of the advancing mats of mycelium. Since these are the only tissues affected to any extent, the fungus must utilize some of the material for food. Whether or not enzymic activity precedes or follows the apparent mechanical destruction of the tissue was not determined. Until the enzymes and the toxins of the fungus are studied, the actual biologic relation of the host and the parasite cannot be accurately determined.

CULTURAL STUDIES

Media

Endothia parasitica grows luxuriantly on a wide range of culture media. The writers, as well as other investigators, have grown it on sterilized twigs of many forest trees, on roots, and on bean plugs, carrots, potatoes, sweet potatoes, bread, corn meal, oatmeal, rice, sugar solutions, bouillon, various synthetic media, and a large number of agar media. In fact, in the saprophytic condition the fungus seems to be almost omnivorous.

Isolation

The fungus is most readily isolated by removing, under sterile conditions, a small piece of the diseased tissue of the inner bark, especially in the

youngest part of the canker, and transferring it to agar tubes. Anderson and Anderson (1913) have described in detail various other methods of isolation. Either kind of spores may be sown on the agar, or streaks may be made on agar slants with the spore horns, or the ascospores may be permitted to fall on agar plates after natural ejection.

General cultural characters

There are certain characters that are common to the growth of the organism on most of the artificial media commonly used, particularly the agars.

Murrill (1906 a:146) says: "When grown in artificial culture, the mycelium of the fungus is at first pure white, changing to yellow with age, and the fruiting pustules are a beautiful yellow." He finds that the fruiting pustules are produced in eleven days, and mature spores in the process of discharge in twenty days. Neither Murrill nor any writer since 1906 has succeeded in producing the ascospore stage in culture.

Clinton (1909:886) describes the same color change on lima-bean agar, and adds: "The threads form a rather hard crust on the surface of the medium, and in this the Cytospora fruiting stage develops as numerous small elevations. The spores, after maturity, ooze out on the pustules as lemon-yellow drops, which later become light chestnut-brown in color."

Anderson and Anderson (1912 a) advocated the cultural characters as a means of distinguishing this species from the other very closely related and confusing species of Endothia. Since then, Pantanelli (1912), Clinton (1913), and Shear and Stevens (1913 a) have studied this phase, and they all find additional cultural characters on a number of media by which these forms may be distinguished. It is not our purpose to discuss these differences in this publication, since they do not directly concern us at this time. Only the most important characters that relate to *E. parasitica* will be mentioned. For a more complete discussion the reader is referred to Shear and Stevens (1913 a), where the cultural characters on a large number of media are described in detail.

Sterilized twigs

On twigs of all the common forest trees that were tried (Anderson and Anderson, 1912 a), the fungus produces a short, white, web-like growth over the surface of the twig, with heavier bunches of mycelium which later become orange-colored, where the pycnidia are to develop. On the cut ends of the twigs there is developed a thick, felt-like, orange mycelial growth, but this never extends out on the bark as in *E. radicalis*. The same characters were found by Shear and Stevens (1913 a), except that

these investigators call the color of the mycelium on the cut surface "cadmium yellow."

Potato agar slants

When streak cultures are made on potato agar slants with spore horns, the mycelium begins along the streak as a white weft and spreads rapidly toward the edge. In four days, at ordinary room temperature, the orange color begins to appear along the streak, and it broadens as the mycelium grows out until the whole surface of the slant is covered with a deep orange growth. This test was used most extensively by the Andersons in distinguishing this species from the other Endothiæ. Shear and Stevens (1913 a: 12) record the same phenomenon on this agar, and add: "Within six days, the mycelium, especially at the base of the agar slant took on a peculiar granular metallic appearance. . . . This portion of the culture was light orange yellow by reflected light and orange by transmitted light. The peculiar surface appearance might perhaps be called 'brassy.' This metallic appearance has been found to be the most constant and reliable distinguishing character of *E. parasitica* on potato agar. In twelve to fourteen days small pycnidial pustules appeared in the upper portion of the tubes, and the agar just below the mycelium became warbler green, changing later to olive green."

Often potato agar cultures after three or four months turn to a deep purple or wine-color. H. W. Anderson (Anderson, P. J., 1914) found that this purple color is due to the fact that the long growth of the organism on the agar causes the latter to lose its acid character and become alkalin. The yellow pigment (aurine) in the mycelium goes into solution in an alkalin medium and turns purple. The pigment then escapes from the cells and is suffused throughout the agar.

Relation of light

The fungus grows just as rapidly in darkness as in light, and also produces the yellow pigment but not so abundantly. D. C. Babcock, working with one of the writers of this bulletin, found, however, that in total darkness no pycnidia are produced, but just as soon as the culture is brought into light the pycnidia begin to form. This fact accounts for the concentric rings of pycnidia so noticeable on plate cultures. One circle is produced each day. Doctor Shear, in a letter to the writers, states that pycnidia are produced in darkness.

Relation of temperature

Shear and Stevens (1913 a: 9) studied the relation of temperature to the growth of the mycelium in pure cultures. Their results are thus

summed up: "From these records it will be noted that the minimum temperature for all was 9° C. and that all failed to grow at 7° C. The maximum temperature for *Endothia parasitica* . . . was 35° C. . . . The optimum appears to be near ordinary room temperature, that is, about 22° to 24° C."

Tannic acid

Since the chestnut tree has a relatively high tannic-acid content, the question naturally arises as to the relation of tannic acid to the growth of the fungus. Clinton (1913:407) grew the fungus on cultures containing various amounts of tannin, and summarizes his results thus: "(1) Both fungi [referring to *E. parasitica* and *E. gyrosa*] can use tannic acid, at least in small amounts, as food — shown by the blackening of media through oxidation, loss of acidity, more luxuriant growth, with a low per cent of the acid added, than without it, and a slight growth on agar-agar with tannic acid as the available source of food. (2) Higher percentages of tannic acid (four per cent and above) are detrimental to a vigorous growth of either of these fungi, and finally (10 to 14 per cent) entirely inhibit their growth. But with the true blight the tolerance is apparently greater by 2 to 4 per cent than that of the saprophytic *E. gyrosa*. (3) Long-continued cultivation of the parasitic variety in artificial cultures without tannic acid probably lowers its tolerance to the higher percentages of tannic acid. (4) Gradually passing these fungi in cultures from the lower to the higher percentages of tannic acid apparently raises their tolerance to it." Clinton suggests that the tolerance of a higher percentage of tannin probably bears some relation to the parasitism of *E. parasitica*.

ECOLOGIC RELATIONS

Murrill (1906 a:153) gives his opinion (1) that winter injury possibly accounted for the epiphytotic, (2) that there was a decline in constitutional vigor, because of coppicing, which predisposed the tree to attack, and (3) that cultural conditions could determine relative resistance to attack. The effect of these ecologic conditions, as well as of drought, in increasing the susceptibility of the tree is upheld by Clinton (1909:887–889; 1911:717; 1913:389–407). In the last publication Clinton (1913:390–391) writes:

"Now, if the condition of the host bears no relation to the rise and spread of the disease, the writer knows of no satisfactory explanation for its sudden and destructive appearance in this country except its importation from some foreign country. The evidence to date, however, is very strongly against the idea that it is an imported pest, as we shall show later. Among the farmers in Connecticut who have been able to watch this disease rather closely there are many who believe that the weakened vitality

of the chestnuts has had considerable to do with its development and spread in this State. The writer more than any one else has advocated this view, and we propose to give here the reasons we have for holding it. Briefly expressed, they are as follows:

"The chestnut blight was brought to sudden prominence just after the severe winter of 1903–1904, which injured and killed fruit and forest trees in general along the coast and watercourses, of which New York City was the central point. The resulting enfeebled condition of the chestnut enabled the blight, a previously inconspicuous parasite, to spring into sudden prominence on these trees and to gain credit for the death of others which had been largely or entirely due to winter injury. Since then we have had one or two severe winters, and more especially several dry summers, that have injured not only the chestnut, but other forest trees over an extended area. Due to its successful attack on the weakened trees, the blight fungus has perhaps acquired an added virulence that has enabled it to attack apparently healthy trees, especially those of sprout renewal. The enfeebled condition of the chestnut trees and their consequent susceptibility to the blight may possibly be related to some lessened chemical activity in the bark and newly-formed wood, such as the production of tannic acid, for instance. If so, then when this has returned to its normal production through favorable weather conditions, the blight should gradually become correspondingly less aggressive."

Opposed to these views we have those of Metcalf and Collins (1910): "A debilitated tree is no more subject to attack than a healthy one. [See also Metcalf, 1910.] Dry weather checks the disease by suppressing spore production. . . . Winter injury is not common over the whole range of the bark disease, but may be locally important in producing lesions through which the parasite enters. Winter injury bears no other relation to the bark disease." Metcalf (1912 a:225) writes: "No definite evidence, experimental or otherwise, has been adduced to show that a tree with reduced vitality is more susceptible to infection, or that the disease spreads more rapidly in such a tree than in a perfectly healthy and well-nourished tree of either seedling or coppice growth, provided that such reduced vitality does not result in or is not accompanied by bark injuries through which spores can gain entrance." (See also Metcalf, 1912 b: 79–82.) The writers think that in the above quotation Metcalf has well summed up the apparent fallacies in the preceding statements made by Clinton.

By observations the writers have found no connection between any ecologic conditions and any variation in the susceptibility of the tree. However, ecologic conditions may determine the rapidity of spread of the fungus through the infection courts opened up, such as winter- and

drought-injured bark and limbs, hail, and other mechanical injuries, and the like

The writers have proved, through thousands of inoculations made in the States of Pennsylvania and New York, that the healthiest trees are entirely susceptible. Winter-injured trees, even if dead, could not be more susceptible.

Anderson and Babcock (1913) were unable to find any conditions under which one tree is more susceptible than another. One of the writers of this bulletin (Rankin, 1914) has shown by a careful series of inoculation and growth studies, along with accurate determinations of the water and air content of the bark, that in 1912, at least, no connection between drought and change in susceptibility was found. The majority of the inoculation work reported in the same paper was performed on coppice growth which had grown from trees cut about five years previously. These trees had not, therefore, been subject to the severe winters which Clinton has claimed, predisposed the chestnut. In no way were the results of inoculations made on this five-years-old coppice any different from those made on older trees. In cutting several trees near Napanoch, a few were found that showed a dead area which may have been produced by the severe winter of 1903–1904. In one case the injured area had decayed, leaving a ring-shake. In other trees no injury was apparent. No difference in susceptibility, however, was noted.

The writers would summarize their belief, based on observation and experiment, that, without regard to any ecologic relations, the native chestnut is entirely susceptible because of the parasitic potentialities of the fungus, which have not heretofore had an opportunity to be demonstrated.

CONTROL

METHODS THAT HAVE BEEN ADVOCATED

Merkel (1906:101–103) attempted to control the disease in the New York Zoological Park, where he first discovered it. In the summer and fall of 1905 he had all the diseased limbs removed from four hundred and thirty-eight trees, and the trees were then sprayed with bordeaux mixture. Only one application was made. No further report appeared on this experiment except the statement of Murrill (1906 b:205): "An attempt was made by Mr. Merkel, chief forester at the Zoölogical Park, to control the disease by spraying, but I believe he considers the condition quite hopeless. Practically all of the chestnut trees within his jurisdiction appear to be dying rapidly."

Murrill (1906 a:152–153) was the first to give advice on control, his advice being as follows:

"The treatment of a disease of this nature must, of course, be almost entirely preventive. When once allowed to enter, it cannot be reached by poisons applied externally, nor can the spores, which issue continuously and abundantly through eruptions in the bark be rendered innocuous by any coating applied at intervals. On the other hand, no poisonous wash, even though covering every part of the tree, can prevent the germination of the disseminated spores when they fall into a wound, since the wound opens up fresh tissues unprotected by the poison.

"The spraying of young trees with copper sulfate solution, or strong bordeaux mixture, in the spring before the buds open might be of advantage in killing the spores that have found lodgment among the branches during the winter, but the real efficacy of this treatment is so doubtful that it could not be recommended for large trees, where the practical difficulties and expense of applying it are much increased. Nursery trees should be pruned of all affected branches as soon as they are discovered, and the wounds carefully dressed with tar or paint or other suitable substance. Vigilance and care should largely control the disease among young trees. With older trees all dead and infected wood should be cut out and burned and all wounds covered without delay."

Murrill (1906 b:209) says also: "I have no treatment to suggest further than the preventive measures already mentioned." In 1908 he adds (1908 a:24–25): "Preventive measures have apparently not affected it in the slightest degree. The pruning of diseased branches has entirely failed to check it, even in the case of very young trees. Branches have been carefully removed and wounds covered, leaving the tree apparently entirely sound, but upon inspection a few weeks or a few months later they would be found badly diseased at other points." In the same publication (page 30) he advises eradication measures for spot infections in the woods: "Owners of standing chestnut timber within the affected area are advised to cut and use all trees, both old and young, that stand within half a mile of diseased trees, unless protected from infection by wind-blown spores, by dense forest growth, or some other natural barrier." Hodson (1908:7) advises: "(1) To cut out the diseased trees, (2) to institute a quarantine against the shipment of infected material."

Metcalf (1908 b:490) also advocated the cutting-out method for limiting the spread of the disease. He writes: "In certain localities where the disease is just appearing it would undoubtedly be possible, by prompt cutting down or treatment of all infected trees and by very careful inspection, to maintain a zone free from the disease, and hence keep the disease out of the still uninfected country beyond." Clinton (1909:890) writes: "No efficacious treatment for the prevention of the trouble has yet been found, though spraying, pruning, and burning of infected trees have been advocated."

Metcalf and Collins (1909: 49–52) take up in detail the means of control of the disease. After stating that the distribution of the fungus to distant points would be accomplished largely by the shipment of diseased nursery stock, they point out the necessity of rigid inspection of nursery stock shipped into uninvaded territory. They also advise a campaign of education in order to acquaint the public with the nature and appearance of the disease. They then point out the necessity of promptly cutting and burning newly affected trees so that spot infections may be arrested. They say: "Almost the only treatment that can at present be safely recommended as surely retarding the spread of the disease to a greater or less extent is one which will never be of practical use except in the case of orchard trees or certain valuable ornamental trees. It consists essentially in cutting out the infected branches or areas of bark and carefully protecting the cut surfaces from outside infection by means of a coat of paint or tar. This cutting must be thoroughly done and the bark of every infected place entirely removed for a distance of at least an inch (where the size of the branch permits) beyond the characteristic, often fan-shaped, discolored areas produced by the growing fungus in the inner bark. All small infected twigs or branches should be cut from the tree, the cut being made well back of the diseased area. A pruning knife with an incurved tip, a hollow gouge, or any other clean-cutting instrument will serve for cutting out diseased spots. . . . The paint or tar may be applied by means of a good-sized brush, care being taken to cover every part of the cutting." (See Figs. 96 and 97.)

It remained for Metcalf and Collins (1911: 10–24) to suggest definite methods for arresting the country-wide progress of the disease. They outlined their method of scouting and cutting-out in detail (pages 12 to 17 of reference cited). The procedure is summarized thus (page 24):

"The only known practical way of controlling the disease in the forest is to locate and destroy the advance infections as soon as possible after they appear and, if the disease is well established near by, to separate the area of complete infection from the comparatively uninfected area by an immune zone. Advance infections should be located by trained observers and destroyed by cutting and burning. As the disease develops almost entirely in the bark, this must be completely destroyed (burned).

"In order to carry out the above methods it is essential that the several States concerned secure necessary legislation and appropriations, following the example of Pennsylvania, as no law exists whereby the Federal Government can undertake such work and cooperation among private owners without state supervision is impracticable."

The method proposed led to much discussion among pathologists. There were a few who openly criticized the method as impractical, and

pronounced it a possible source of wasteful expenditure of state money. Others were more neutral and awaited additional evidence. The majority, however, were of the opinion that further research must be made before the practicability of any method could be actually proved. Stewart (1912) gave many reasons for not indorsing the method. He said: (1) the method was not supported by experimental evidence; (2) "no such method of controlling a fungous disease has ever been attempted"; (3) known facts concerning the disease did not make the method appear feasible; and (4) "it is better to attempt nothing than to waste a large amount of public money on a method of control which there is every reason to believe cannot succeed."

FIG. 96.— *Method of cutting out a canker on the trunk. The wood is cut out an inch below the bark*

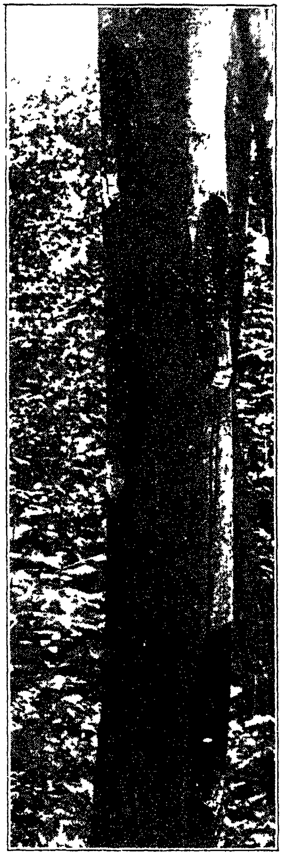

FIG. 97.—*Trunk from which four cankers have been cut out. After sterilization the wounds are completely coated with a wound dressing*

Murrill (1912) thus presents his views as to why the chestnut canker cannot be controlled by the cutting-out method:

"1. It is impossible to locate all advance infections, these not being apparent even under close inspection.

"2. It is practically impossible to cut down and burn all infected trees after their discovery.

"3. Even if these trees are cut, it is impossible to discover and eradicate the numerous infections originating from millions of spores produced on these trees and distributed by birds, insects, squirrels, wind, and rain.

"4. Even if it were possible to cut and burn all affected trees, for ten to twenty years afterwards numbers of sprouts would grow up from the

roots of these trees and continue to die from the disease and to spread the infection.

"5. Supposing that it might be possible to eradicate all advance infections, what method is proposed that is at all feasible for combating the disease in its main line of advance? All of the foresters connected with the United States Government and the entire army of the United States would be utterly powerless to oppose its progress.

"6. Although the chestnut canker has been known and experimented with since 1905, there is not a single instance where an individual tree or a grove of trees affected by the disease has been saved. If it is impossible to combat the canker under the most favorable circumstances, how would it be possible to succeed with an extensive forest? The published account of the extermination of the chestnut canker in the vicinity of Washington, D. C., cannot be relied upon. The trees most conspicuously affected there have been cut and burned, so that the presence of the disease is not readily apparent, but with each season additional trees will be affected and the attempt to stay the disease will be abandoned, especially when the main line of advance, which is now in northern Maryland, reaches the Potomac River."

Clinton (1912 c:82) says that in the main he agrees with Stewart and Murrill.

Some months previous to this discussion the State of Pennsylvania had appropriated a large sum of money for the investigation and control of the chestnut-tree blight disease. Metcalf and Collins (1911:14–17) quote this act, which embodies the scouting and cutting-out method described in the same publication.

During the summer of 1911 Doctor Metcalf appointed several agents who scouted in a preliminary manner the different States concerned in the control of the disease. With the information thus available (Metcalf and Collins, 1911:6), the authorities of the different States considered means of controlling the disease. Those States north of Pennsylvania took no definite action, mainly for two reasons: (1) the cutting-out method (the only method proposed) was not sanctioned by some persons to whom the state authorities looked for advice; (2) the disease had gained such a foothold that its economic control by the cutting-out method could hardly be expected by the most radical supporters of the method.

The published reports on field operations for the control of the disease in Pennsylvania are limited to the reports for the period from July 1 to December 31, 1912. The work of organization and preliminary scouting occupied the interval from the time of the appointment of the Commission in the summer of 1911 until the spring of 1912. The Commission reports (Penn. Chestnut Tree Blight Com., 1913:11):

"From the beginning, a more or less definite division has been maintained between the slightly infected western portion of the State and the badly infected eastern portion, these divisions being called the Western and Eastern Districts, respectively. In the two districts quite different restrictions are maintained with respect to the method of procedure in handling diseased trees. The line of demarcation between these districts, as at present understood, is the eastern boundary lines of Fulton, Huntingdon, Mifflin, Center, Clinton, Lycoming, Sullivan, and Bradford Counties. . . . The field work [page 21] west of the advance line has for its object primarily the total eradication of the blight, and the checking of further westward spread. East of the advance line where the bulk of the chestnut trees is located, it is the duty of the Commission to acquaint owners of timber with the facts relating to the blight. . . . at least in time to cut out the diseased trees before they deteriorate in commercial value. . . . In each district a district superintendent has been appointed to direct the field work. . . . The western district was subdivided into seven divisions of five to seven counties each, and five divisions were made in the eastern district. Each division has been in charge of a Supervisor. A field agent was detailed to conduct the work in a county and as many scouts as necessary were assigned him as assistants. . . . When the examination [page 23] of each tract was completed a data card, giving all the necessary information relative to the tract, was sent to Field Headquarters . . . The plan [page 25] now being followed when a spot infection is found is to blaze the infected trees at breast height and also at the base . . . and the infected trees numbered consecutively. . . . The points [pages 26–27] to be emphasized in eradicating spot infections are:

"1. Take all possible care to prevent injuries to surrounding chestnut trees and sprouts in felling the infected tree. If it is necessary to clear away brush to facilitate cleaning up after felling, any small chestnut sprouts should be cut flush with the ground. Experience has shown that such stubs often become infected if near a diseased tree.

"2. Cut all stumps as low as possible, to lessen expense of peeling and to save merchantable timber in the log.

"3. Destroy all diseased portions of the tree showing pustules, by burning on the spot, immediately, either the bark or entire sections of the tree which show cankerous areas.

"4. Either utilize all unbarked portions of infected trees within a brief time after they are cut, or, if it is desired to permit this material to remain in the vicinity of healthy chestnut trees, peel the bark from all portions of the trees which it is desired to retain.

"5. In every case peel the bark clean from the stumps to an inch or

two below the surface of the soil. Experience has shown that the stumps of infected trees and portions of the green tops which are permitted to lie for several months on the ground, are almost certain to become infected if the bark is permitted to remain on them, even though no cankers exist on the stump at the time the tree is cut. Some of the largest spots of infection have developed from unpeeled stumps. The spores germinate on the sappy surface of the stump and the mycelium grows downward through the cambium, and in the course of a year or two reaches the sprouts which come around the base of the stump. Little infection in the sprouts is found where the stumps have been carefully peeled. Furthermore, the sprouts have more vigor and are better rooted when they come from peeled stumps, since in this case they must start from beneath the soil and can so form their own roots." (Figs. 98 to 101.)

FIG. 98.— *Peeling the base of a diseased tree. Woodsmen find this easier than peeling the stump after the tree is cut*

As to the results of the cutting-out method, the following is quoted from the same report (page 27): "Sufficient time has not elapsed since the Commission began work to determine the efficiency of sanitation in checking the disease. . . . Forty-two tracts on which the original infection was cut out during the early part of 1912 were reinspected during November and December of this year (1912). The number of diseased trees in these spots prior to cutting ranged from a single tree to ninety-three, the total number of diseased trees on the forty-two spots being five hundred

and fifty-six. On reinspection, twenty-eight out of the forty-two spots showed no recurrence of the blight; in three cases a single new infection was found, and in six cases there were two recently infected trees. The highest number of new infections numbered thirteen trees. In the forty-two spots averaging 13.25 original infected trees each, one hundred and fifty-six reinfections occurred, or 3.7 infections per spot. In two thirds of the forty-two spots no blight reappeared, and the new infections which developed in the remainder equaled only two sevenths of the number of trees originally diseased. These spots were located in the region of very slight infection in Elk, Clearfield, Center, and Fulton counties."

FIG. 99.—*Cutting down the tree that has been peeled at the base*

The results of the oldest experiment that is reported are as follows (pages 32–33 of the same report):

"In order to get information concerning the effectiveness of two different methods of cutting out diseased chestnut, a stump-to-stump count of 100 stumps each was made in November, 1912, on two different tracts located at Haverford. In one of the woodlots the infected trees were cut in the fall of 1910, and the stumps peeled, and all brush destroyed by burning, but the burning was not done over the stumps. On this tract a hundred stumps had 1354 vigorous

sprouts, on 254 of which the blight was present. In other words, 82 per cent of these sprouts were free from disease, and of the infected sprouts, 99, or 39 per cent, were infected at the base mostly from diseased bark left on the stump.

"The second tract, used for comparison with this, is located about one half mile distant from the first tract and was cut about the same time. The brush was burned and all the merchantable wood used, but the stumps were not peeled. As near as could be determined, the two woodlots received identical treatment except that the stumps were peeled in one case while they were left with the bark on in the other. On this

FIG. 100.— *Peeling the trees that had cankers*

tract the 100 stumps had 1406 vigorous sprouts, 1115, or 79.3 per cent of which were infected, 22.2 of the infections were basal."

The Pennsylvania Commission, after having started these extensive state-wide experiments in control, passed out of existence in July, 1913, through failure of the Legislature to appropriate sufficient funds with which to continue the work as it had been begun. Much that was valuable had been accomplished in scientific research, but the field experiments in cutting-out, on which the greater part of the $275,000 was spent, were only begun and can in no wise be of more than very temporary benefit to the State.

In New York State the survey made by one of the writers of this bulletin proved that the disease had a greater stronghold than had been supposed. With the vast area that was then affected, the problem of control

presented many difficulties. The chestnut in the part of the State west of the line of advance (Fig. 78) was of considerable value and worthy of being saved if this had been economically possible. The region that contained the greatest amount of the valuable chestnut timber of the State, however, lay in the hopelessly affected area. One of the writers, in making a report to Doctor Metcalf in October, 1911, made the following statements: "It is well, however, to consider the difficulties involved. The advancing line [Fig. 78] is in a region in which the topography is extremely rough, the hills are thickly wooded, and the chestnut is

FIG. 101.— *Burning the branches over the stumps. All broken-off branches and chips are raked up and burned*

abundant. Under such adverse conditions, it would be, to say the least, a gigantic task if not indeed an impossible one. If natural barriers were more favorable, such a scheme might be more feasible." No special appropriation or plan to control the disease was made. The position of State Forest Pathologist was inaugurated in July, 1912, and one of the writers was appointed to this position. Field investigations on the chestnut canker were conducted until October, 1913. These are reported elsewhere (Rankin, 1914).

The writers understand that West Virginia and Virginia (Gravatt, 1914) are scouting for spot infections and eradicating them as fast as

possible. No elaborate organization has been attempted and no large sums of money have been appropriated for these operations. The regular authorities are in charge of the work. The Office of Forest Pathology at Washington is still maintaining research work on the disease and has employed S. B. Detwiler, formerly in charge of the field operations in Pennsylvania, to check the results of the cutting-out done in western Pennsylvania. The report on this work is soon to be published (Detwiler 1914). North of Maryland no attempt is being made to control the disease.

GENERAL DISCUSSION OF CONTROL MEASURES

Exclusion measures

In regions still unaffected the consideration of exclusion measures is highly important. Diseased nursery stock has been proved the mos dangerous means of introduction of the fungus into new localities. Th original spot infections in this country were, without much doubt, starte from diseased nursery trees shipped from the Orient. Five out of nin of the spot infections in western Pennsylvania were traced to disease nursery stock. The only spot infection known in western New York — at Penn Yan — was in an orchard.

In order to prevent the shipment of diseased stock the trees should b inspected when they are packed and again when they reach their des tination. A blanket certificate issued yearly to nurseries is worthless i the case of this disease, as with many others. As a part of the contrc measures instituted by the Pennsylvania Commission, all nursery trees wer inspected and tagged individually before packing. The inspection of tree at their destination is not always sure to exclude diseased trees, fo incipient infections are likely to be overlooked.

Because of the uncertainty of inspection of shipments and the extrem virulence of the parasite, it seems highly desirable that an absolut quarantine be placed on the affected region of the eastern United States which would prevent the shipment of chestnut stock outside the prescribe limits. This would protect outlying or distant parts of our own countr and would aid foreign countries in excluding the disease. It is especiall incumbent on foreign countries that have chestnut to protect, to take th most rigid measures in order to prevent this disease from gaining a foot hold.

The fact that diseased nursery stock is not the only means of transport ing the fungus from an affected region must not be overlooked. Part of diseased trees barked or unbarked may serve to carry the fungus The following points show the danger there is in transporting unpeele

logs or tree parts outside the affected regions (1) ascospores will germinate after having been kept dry for two and one half years, (2) conidia will germinate after having been kept dry for at least a year; (3) mycelium retains its vitality after having been kept dry for at least ten months; (4) perithecia, after having been kept dry for seven months, will again eject spores on being moistened.

Peeled timber may serve to carry the fungus, for the mycelium, which penetrates at times to the fifth annular ring of the wood, will under moist conditions produce superficial pycnidia and spore horns on the surface of the wood.

There are chances, of course, that even a strict quarantine on nursery stock or chestnut products will not eliminate all the means of introduction into a new territory. The fungus, in the form of either mycelium or spores, may be carried on or in other plant parts or by birds, wind, or other uncontrollable agents.

Eradication measures

There are two kinds of conditions under which eradication measures may be carried out, namely, arboricultural conditions and forestry conditions. In the case of orchard and ornamental trees the principles of sanitation and tree surgery have been advanced for the control of the canker. But even as early as 1908 Murrill says these means are without avail. Vast sums of money were expended by individuals in order to save such trees in cities and on private grounds in the regions first affected. Failure attended all attempts. This was largely due to four reasons: (1) the work was done by commercial tree surgeons who had had no special training; (2) it is impossible to find and remove all affected parts of a diseased tree, especially incipient infections and cankers under rough bark; (3) reinfection is constantly possible; and (4), a reason not the least in the majority of cases, the fact that the mycelium entered deeply into the wood was ignored, and the cankers renewed growth by the mycelium growing from the wood back into the bark. The last-named fact has been brought out by experiments conducted by Collins (1912 a) and by members of the staff of the Pennsylvania Commission (1912 b:2).

The removal of dead and dying trees and of all refuse from the surgical operations is necessary. Also all wounds must be protected immediately by an enduring covering (Fig. 97, page 598). Ample suggestions in regard to surgical methods are given by Metcalf and Collins (1911:18–20), Collins (1912 a), Pennsylvania Chestnut Tree Blight Commission (1912 b), and others. A later report (Pennsylvania Chestnut Tree

Blight Commission, 1914) says that careful tree-surgery work will often save affected trees.

With regard to the eradication measures to be applied in the forest, the cutting-out method of Metcalf and Collins (1911: 10–17) embodies the principles mentioned above. The method, although put into practice in Pennsylvania in 1912 and 1913, will not now, it seems, be demonstrated, since all concerted attempt at country-wide control has been abandoned. At the present time, however, we can theorize on the practicability of the method with more certainty than was possible at the time of its original consideration in 1911.

The writers believe that the method would not have succeeded economically even if it had been vigorously prosecuted from the time of its proposal. In addition to the reasons given by Stewart (1912) and Murrill (1912) which in their opinion make the method impossible, later research has constantly added evidence of the important part played by numerous disseminating agents that must be reckoned with. Careful surveys and the elimination of all spot infections outside the affected region would accomplish temporary control. But even with a carefully executed quarantine on nursery stock and chestnut products, the chances of reinfection from a distance or reappearance at an old spot infection would necessitate constant resurveys, which, if thorough, would be expensive and could not even then be expected to absolutely eradicate the disease. The principal difficulty, however, would be the main line of advance, where on the one side nothing would be done and immediately adjacent complete control would be attempted by eradication. The immune zone suggested in this scheme is the only way of meeting this. Just how wide such a zone would have to be in order to obviate infection due to wind dissemination of ascospores would vary with conditions. The chestnut-free belt in the Catskill Mountains, varying from thirty to forty miles in width, has apparently furnished protection for the area west of the mountains. The mere felling and utilization of all the trees, however, in a zone twenty miles around the affected area as it was in 1911, would be an enormous task, consuming much time and money. Taking into consideration the work and the money required in order to put the whole scheme into operation, it does not seem logical to believe that the chances of success warrant the risk.

Hope is expressed in a publication by Craighead (1912), who states that certain insects found eating the perithecial pustules of the canker fungus may aid in eradicating the fungus. Ruggles (Penn. Chestnut Tree Blight Com., 1914), however, writes: "The particular insect (*Leptostylus maculata*), carrying the 336,900 spores mentioned is one of the beetles named in a recent press notice of the United States Depart-

ment of Agriculture, as being very active in eating spores of the blight fungus. Therefore this beetle while destroying spores of the blight is at the same time covering its body with thousands of other chestnut blight spores which it carries from tree to tree, making it probably an injurious insect instead of a beneficial one in this respect."

Protection measures

The only experiments reported on spraying were those of Merkel and the Pennsylvania Commission. The single application of bordeaux mixture made at the New York Zoological Park by Merkel in 1905 failed to check the disease. The Pennsylvania Commission conducted spraying experiments at Kenneth Square, Pennsylvania. Bordeaux mixture 4–4–50 was applied with a power sprayer every two weeks from April until the middle of November, 1912. No definite results are reported from this experiment (Penn. Chestnut Tree Blight Com., 1913:51, Figs. 53–55).

Immunization measures

Many writers have suggested the possibility of selecting and breeding immune varieties. Morris (1914) sums up observations on different varieties planted among affected American chestnuts. Van Fleet (1914) has found Asiatic chinquapin hybrids promising. With the relatively high degree of resistance shown by the Japanese and Chinese chestnuts, there may be a possibility of breeding within these varieties. Crosses with the American chestnut seem hopeless. Metcalf and Collins (1911:20) write: "If the seed [of Japanese chestnuts] is raised in America, the trees are more than likely to be hybrids with the American chestnut and to vary greatly in resistance to the bark disease."

The investigators of the Pennsylvania Commission applied many kinds of fertilizers around trees and carefully recorded the effect on the rate of growth of cankers. At Mount Gretna, Pennsylvania, the following substances were used in different combinations and quantities: burned lime, nitrate of soda, acid phosphate, muriate of potash, and kainit. At Emilie, Ambler, and Valley Forge, Pennsylvania, iron filings and coal and wood ashes, in addition to the substances mentioned above, were applied. At Mount Gretna the trees were old and thick-barked. The cankers were outlined in spring at the time of application, and again in late fall. When the measurements were compared with the checks no differences were found except within the limits of the usual variations. In the experiments at Emilie, Ambler, and Valley Forge no variation on rate of growth of cankers was obtained.

Also, at Emilie many secret preparations, applied as fertilizers or as injections, were tried. These were methods advocated by various laymen

who considered they had a specific for the control of the canker. One of the writers of this bulletin served as a member of the Board of Review (Penn. Chestnut Tree Blight Com., 1914) which passed on the records of these tests as well as on those of the fertilizer tests. The report of the board stated that not one of the treatments had affected in the least the rate of growth of the cankers. In a large number of cases, only single very small cankers were present on the trees at the time of treatment, so that the tests were fair.

Many methods of tree medication have been brought forth by quacks since the chestnut canker began its ravages. The Pennsylvania Commission furnished trees for testing these methods to all who applied for a test to be made of their specific. As mentioned above, these all failed to produce the desired effect.

Dr. C. Rumbold (Penn. Chestnut Tree Blight Com., 1913:45-47) has been working on the effect of different substances injected into the chestnut, but as yet has reported no successful results.

RECOMMENDATIONS FOR TIMBER OWNERS IN NEW YORK STATE

The warning may well be repeated against planting chestnut anywhere for orchard or ornamental purposes. The speedy utilization of all diseased trees may serve as a local temporary control measure if carefully carried out. However, as it is now apparent that little can be done to control the disease, the consideration of the best means of utilizing the present stand is important to the timber owner (Nellis, 1914).

Three separate conditions exist in New York State at present: (1) in the Hudson River valley, conditions exist varying from total destruction to more or less numerous spot infections; (2) in the Roundout and Delaware River valleys, spot infections are numerous and probably but little damage has been done to the trees as a crop; (3) west of the Delaware River valley, spot infections are few and of small extent. It is important, then, to consider what can be done in these different sections in order to minimize the damage.

In the Hudson River valley it is a question of speedy utilization of dead and dying trees for the most part. This is a necessity for two reasons: (1) in order to obtain profit for the owner which will otherwise be decreased, and (2) in order to rid the section of this disease- and insect-breeding material. The owner will undoubtedly find some more or less profitable market for the greater part of the accessible timber now going to waste, if he makes a study of his local conditions. He may also obtain information from the federal and state departments. The importance of ridding the country of the dead material, which will otherwise become a breeding-place for other fungi and insects, cannot be overestimated.

In the Delaware and Roundout River valleys it is a question of utilization of immense quantities of second-growth chestnut of small dimensions. It seems that the work in this region, as well as in the Hudson River valley, is of a magnitude sufficient to warrant a careful study by the proper state officials in order that owners may receive helpful advice on conditions, markets, and methods. This would be an immediate phase of conservation worth while to the State of New York.

In the central and western parts of the State a careful watch should be kept for new spot infections, and the diseased trees eradicated as soon as discovered. Plans for future replacement of chestnut by other species should be made now, even before the chestnut dies, so that a forest may be growing up in the meantime.

One important factor to be considered at present through the whole State, and especially the eastern part, is what will become of the land that previously has grown chestnut. Careful study should be made of silvicultural conditions in these regions, followed by an attempt to obtain a stand of a desirable species that will replace the chestnut. Otherwise the tree weeds and other factors will interfere and will increase indirectly the damage done by the canker.

THE OUTLOOK

At present we know of nothing that will prevent the extermination of the American chestnut tree. Every measure of control that has been tried has been abandoned north of West Virginia and the Potomac River. Some persons have expressed the belief that nature herself will intervene to prevent destruction of the species; the virulence of the pathogen will abate, the resistance of the host will be increased, or natural enemies — insects or fungous parasites — will destroy, or at least check, the pathogen. Up to the present, however, there has been no indication of relief along any of these lines. But we do not believe that the ingenuity of our scientists has been exhausted; that further research will bring to light some method of combating the disease is not beyond the limit of probability. Such research not only should be continued, but also should be augmented; even if effective control measures will not be evolved until it is too late to save the present stand of chestnut, they will be of service in combating other forest epidemics which will undoubtedly come in the future.

ACKNOWLEDGMENTS

The writers wish to acknowledge their indebtedness to Professors Reddick and Whetzel, of the Department of Plant Pathology, New York State

College of Agriculture, for suggestions during their investigations and for criticism of their manuscript; to the New York State Conservation Commission and the Pennsylvania Chestnut Tree Blight Commission, in whose employ the majority of the writers' investigations were made; and to Dr. Haven Metcalf, of the Office of Forest Pathology, Washington, D. C., for much valuable collaboration.

BIBLIOGRAPHY

Anderson, P. J.

1913 Wind dissemination of the chestnut blight organism. Phytopath. 3:68.

Abstract of paper read before the American Phytopathological Society, January, 1913. Experiments show that spores are carried in great numbers by the wind.

1914 The morphology and life history of the chestnut blight fungus. Pennsylvania Chestnut Tree Blight Com. Bul. 7:1–44.

Histological studies on the development of the fruit bodies.

Anderson, P. J., and Anderson, H. W.

1912 a The chestnut blight fungus and a related saprophyte. Phytopath. 2:204–210.

Describe the closely related saprophytic species of Endothia as *E. virginiana* sp. nov., and describe the characters separating it from the blight fungus.

1912 b Endothia virginiana. Phytopath. 2:261–262.

Give a scientific description of the new species and propose the combination *Endothia parasitica* as a name for the blight fungus.

1913 The chestnut blight fungus and a related saprophyte. Pennsylvania Chestnut Tree Blight Com. Bul. 4:1–26.

Give the same data as are contained in the previous article under this title in Phytopathology, but in greater detail.

Anderson, P. J., and Babcock, D. C.

1913 Field studies on the dissemination and growth of the chestnut tree blight fungus. Pennsylvania Chestnut Tree Blight Com. Bul. 3:1–32.

Dissemination, rate of growth of cankers at all seasons of the year, and factors influencing susceptibility and rate of growth.

Clinton, G. P.

1908 Notes on fungous diseases, et cetera, for 1907. Connecticut Agr. Exp. Sta. Rept. 31–32 (for 1907–1908):345–346.

Reports the presence of the disease in Connecticut, but does not consider the situation alarming.

1909 Chestnut bark disease, *Diaporthe parasitica* Murr. Connecticut Agr. Exp. Sta. Rept. 31–32 (for 1907–1908):879–890.

Discusses symptoms of the disease, distribution in Connecticut, and the causal organism. Presents arguments supporting his theory that winter and drought injury are predisposing factors in the epidemic.

Clinton G. P.— (*continued*)

1911 Notes on plant diseases of Connecticut. Connecticut Agr. Exp. Sta. Rept. **33–34** (for 1909–1910): 716–717, 725.
Author discusses distribution in Connecticut and his belief that the fungus is of native origin. Japanese and European chestnuts proved susceptible.

1912 a The relationships of the chestnut blight fungus. Science **36**: 907–914.
Discusses the three forms of Endothia in America as *E. radicalis* (linear-spored), *E. gyrosa* (narrowly-oval-spored) and *E. gyrosa* var. *parasitica* broadly-oval-spored, the true chestnut-blight fungus), thus considering the blight fungus as a variety of the native saprophytic form.

1912 b Chestnut blight fungus and its allies. Phytopath. **2**: 265–269.
Author repeats his arguments given in Science in the same month, and states that he has solved the mystery of Schweinitz's lost specimen of *Sphaeria gyrosa*.

1912 c Some facts and theories concerning chestnut blight. Pennsylvania Chestnut Blight Conference. Stenographic rept., p. 75–83. Harrisburg, 1912.
Author presents arguments to support his belief that the fungus is of native origin and that weather conditions are a predisposing factor.

1913 Chestnut bark disease. Connecticut Agr. Exp. Sta. Rept. **36** (for 1912): 359–453.
Historical summary, distribution, description of fungus, synonymy, reasons for believing the fungus is of native origin, weather conditions as a predisposing factor, arguments against practicability of the cutting-out method, bibliography.

Collins, J. F.

1911 The chestnut bark disease. Northern Nut Growers' Association. Proceedings of the second annual meeting. (Unpaged reprint consulted.)
General address on the disease.

1912 a Treatment of orchard and ornamental trees. Pennsylvania Chestnut Blight Conference. Stenographic rept., p. 59–69. Harrisburg, 1912.
Detailed description of tree-surgery methods.

1912 b Some observations on experiments with the chestnut bark disease. Phytopath. **2**: 97.
Abstract of paper read before the American Phytopathological Society, December, 1911. Failure of tree-surgery methods due to the fact that the mycelium penetrates the wood. Author does not believe that conidia are disseminated by the wind.

1913 The chestnut bark disease on chestnut fruits. Science **38**: 857–858.

Cook, M. T.

1911 The relation of parasitic fungi to the contents of the cells of the host plants. Delaware Agr. Exp. Sta. Bul. 91: 21.
Effect of different percentages of tannin on growth of the fungus in culture.

Craighead, F. C.

1912 Insects contributing to the control of the chestnut blight disease. Science **36**: 825.
Finds that the stromata are eaten by five different species of insects, and considers them instrumental in checking the spread of the fungus.

Detwiler, S. B.

1914 Report of field operations of the Pennsylvania Chestnut Tree Blight Commission. Pennsylvania Chestnut Tree Blight Com. Bul. 8:—. (In press.)

Fairchild, David

1913 The discovery of the chestnut bark disease in China. Science **38**:297–299.

Reports the discovery of the chestnut blight fungus as parasitic on chestnuts in China, substantiating Metcalf's theory of its origin.

Farlow, W. G.

1912 a [No title]. Pennsylvania Chestnut Blight Conference. Stenographic rept., p. 70–75. Harrisburg, 1912.

Author presents arguments to support his view that the fungus of the chestnut-tree blight is identical with *Endothia gyrosa*.

1912 b The fungus of the chestnut-tree blight. Science **35**:717–722.

Discusses the American species of the genus Endothia and their relation to the chestnut-blight fungus.

Fleet, Walter Van

1914 Chestnut breeding experience. Journ. heredity **5**:19–25.

Observations on susceptibility and resistance in experimental chestnut-breeding plots.

Fulton, H. R.

1912 Recent notes on the chestnut bark disease. Pennsylvania Chestnut Blight Conference. Stenographic rept., p. 48–56. Harrisburg, 1912.

Air currents as carriers of conidia, effect of temperature on spore germination, summary of intensive observations on a spot infection.

Gardner, M. W.

1914 Longevity of pycnospores of the chestnut blight fungus in the soil. Phytopath. **4**:51–52.

Abstract of paper read before the American Phytopathological Society, December, 1913. Pycnospores washed down into the soil do not lose their vitality. Some survived one hundred and nineteen days of desiccation in soil in the laboratory.

Giddings, N. J.

1912 The chestnut bark disease. West Virginia Agr. Exp. Sta. Bul. 137:209–225.

A bulletin of general information, with map showing distribution of the disease in West Virginia.

Gravatt, Flippo

1914 The chestnut blight in Virginia. Dept. Agriculture and Immigration of Virginia. Unnumbered bulletin dated Jan. 1, 1914.

Gives general description of the disease, location in Virginia (eighteen counties in northern part), directions for eradication of spot infections; advises cutting and utilization of diseased trees in the forest, and treatment of valuable individual trees.

Graves, A. H.

1912 The chestnut bark disease in Massachusetts. Phytopath. **2**:99.

Abstract of paper read before the American Phytopathological Society, December, 1911. Distribution of the disease in Massachusetts.

Heald, F. D.

1913 a The symptoms of chestnut tree blight and a brief description of the blight fungus. Pennsylvania Chestnut Tree Blight Com. Bul. 5:1–15.

Illustrated with sixteen good plates.

1913 b A method of determining in analytical work whether colonies of the chestnut blight fungus originate from pycnospores or ascospores. Mycologia **5**:274–277.

Heald, F. D., and Gardner, M. W.

1913 a Preliminary note on the relative prevalence of pycnospores and ascospores of the chestnut-blight fungus during the winter. Science **37**:916–917.

Authors found that large numbers of pycnospores were washed down the trunks during winter rains, but no ascospores.

1913 b The relative prevalence of pycnospores and ascospores of the chestnut blight fungus during the winter. Phytopath. **3**:296-305.

See annotation under above.

Heald, F. D., Gardner, M. W., and Studhalter, R. A.

1914 Wind dissemination of ascospores of the chestnut blight fungus. Phytopath. **4**:51.

Abstract of paper read before the American Phytopathological Society, December, 1913. Authors prove that spores are blown more than three hundred and eighty feet from diseased trees.

Heald, F. D., and Studhalter, R. A.

1913 Preliminary note on birds as carriers of the chestnut blight fungus. Science **38**: 278–280.

Authors were able to isolate large numbers of spores from birds that were shot.

Hodson, E. R.

1908 Extent and importance of the chestnut bark disease. U. S. Forest Service. Unnumbered circular, p. 1–8.

Discusses symptoms, distribution, dissemination, damage, utilization, and measures of exclusion and eradication.

Höhnel, Fr. von

1909 Fragmente zur mykologie. K. Akad. Wiss. [Wien.] Sitzber. **118**:2:1479–1481.

States that Valsonectria is synonymous with Endothia, and that the chestnut-blight fungus is identical with *Endothia gyrosa* (Schw.) Fückel.

Keefer, W. E.

1914 Pathological histology of the Endothia canker of chestnut. Phytopath. **4**:191–200.

Merkel, Hermann W.

1906 A deadly fungus on the American chestnut. New York Zool. Soc. Ann. rept. **10**: 97–103.

First publication regarding occurrence of the disease in America. Describes symptoms and spraying experiments.

Metcalf, Haven

1908 a The immunity of the Japanese chestnut to the bark disease. U. S. Plant Indus. Bur. Bul. 121:55–56.

Gives distribution of the disease, believes the Japanese chestnut to be the only immune variety, and suggests that the fungus may have been introduced from Japan.

Metcalf, Haven—*(continued)*

1908 b Diseases of ornamental trees. U. S. Agr. Dept. Yearbook **1907**:489–490.
Describes symptoms and recommends eradication measures for control.

1910 The present status of the bark disease of the chestnut. Science **31**:239.
A brief general discussion.

1912 a The chestnut bark disease. Journ. econ. ent. **5**:222–226.
A general discussion.

1912 b Diseases of the chestnut and other trees. Massachusetts Hort. Soc. Trans. **1912**:1·73–90.
A general treatment of the disease. Arguments against the winter- and drought-injury theory.

1913 The chestnut bark disease. U. S. Agr. Dept. Yearbook **1912**: 363–372.
General information.

1914 The chestnut bark disease. Journ. heredity **5**:8–18.
The finding of the disease in the Orient, symptoms, present distribution, et cetera.

Metcalf, Haven, and Collins, J. F.

1909 The present status of the chestnut bark disease. U. S. Plant Indus. Bur. Bul. 141:45–53.
Discuss history, distribution, cause, and symptoms, and restriction of spread by inspection of diseased nursery stock, prompt destruction of diseased trees, and treatment of diseased trees.

1910 The chestnut bark disease. Science **31**:748.
Abstract of a general paper on the disease, read before the American Phytopathological Society, December, 1909.

1911 The control of the chestnut bark disease. U. S. Agr. Dept. Farmers' bul. 467:1–24.
A general discussion of the disease, followed by recommendations for its control by eradication measures. The cutting-out method proposed.

1912 The present known distribution of the chestnut bark disease. Science **35**:421.
A short explanation, accompanying map showing distribution in United States.

Mickleborough, John

1909 A report on the chestnut tree blight. Pennsylvania Forestry Dept. Unnumbered bulletin, p. 1–16.
Reports the presence of the disease in six counties of eastern Pennsylvania.

Morris, Robert T.

1914 Chestnut blight resistance. Journ. heredity **5**:26–29.
Observations on resistance of different varieties.

Murrill, W. A.

1906 a A serious chestnut disease. Journ. New York bot. garden **7**:143–153.
Records isolation and pure-culture studies, results of inoculations, symptoms; recommends sanitation measures for control.

1906 b Further remarks on a serious chestnut disease. Journ. New York bot. garden **7**:203–211.
Records further results of inoculation experiments and failure of Merkel's spraying experiments; recommends various eradication measures for control.

Murrill, W. A.—(*continued*)

1906 c A new chestnut disease. Torreya **6**:186–189.
Describes the causal organism as *Diaporthe parasitica* sp. nov. Diagrammatic figures.

1908 a The spread of the chestnut disease. Journ. New York bot. garden **9**:23–30.
Discusses distribution, failure of eradication measures, varietal susceptibility; recommends rapid utilization.

1908 b The chestnut canker. Torreya **8**:111–112.
Discusses distribution, varietal susceptibility, and failure of sanitation measures.

1910 Occurrence of the chestnut canker. Mycologia **2**:251.

1912 The chestnut canker convention. Journ. New York bot. garden **13**:41–44.
Author discusses reasons why, in his estimation, chestnut canker cannot be controlled, and proposes questions for further scientific investigation.

Nellis, J. C.

1914 Uses for chestnut timber killed by the bark disease. U. S. Agr. Dept. Farmers' bul. 582:1–24.

Pantanelli, E.

1911 Sul parassitismo di Diaporthe parasitica Murr. per il castagno. Accad. Lincei. Rend. 5:**20**:366–372.
Describes successful inoculations on European chestnuts, and decides, after comparisons with other species of Diaporthe on chestnut in Europe, that this is a species new for Europe.

1912 Su la supposta origine europea del cancro americano del castagno. Accad. Lincei. Rend. 5:**21**:869–875.
Decides that the European *Endothia radicalis* is a distinct species from *Endothia parasitica* of America, morphologically and pathologically, and that the latter is parasitic on the European chestnuts.

Pennsylvania Chestnut Tree Blight Commission

1912 a The chestnut blight disease. Pennsylvania Chestnut Tree Blight Com. Bul. 1:1–9.
Discussion of means of identification, remedies suggested, and need of cooperation in order to control and eradicate the blight.

1912 b Treatment of ornamental trees affected with the blight disease. Pennsylvania Chestnut Tree Blight Com. Bul. 2:1–7.
Discusses questionable remedies, methods for tree surgery, beneficial effects of fertilizing, symptoms.

1913 Report of the Pennsylvania Chestnut Tree Blight Commission for 1912, p. 1–67.
Contains brief reports of the various officers and investigators of the commission.

1914 Final report of the Pennsylvania Chestnut Tree Blight Commission. Pennsylvania Chestnut Tree Blight Com. Bul. 9:—. (In press.)

Rane, F. W.

1911 The chestnut bark disease. Massachusetts State Forester. Unnumbered pamphlet, p. 1–7.
A bulletin of general information.

1912 The chestnut bark disease. Massachusetts State Forester. Unnumbered pamphlet, p. 1–10.
Discusses distribution in Massachusetts, symptoms, and methods of control; advises rapid utilization.

Rankin, W. H.

1912 a The chestnut tree canker disease. Phytopath. **2**:99.
Abstract of paper read before the American Phytopathological Society, December, 1911. Reports the forcible discharge of ascospores, and the presence of the superficial pycnidia on wood.

1912 b How further research may increase the efficiency of the control of the chestnut bark disease. Pennsylvania Chestnut Blight Conference. Stenographic rept., p. 46–48. Harrisburg, 1912.
Calls attention to the importance of wind-blown ascospores; reports the closely related saprophytic form in Virginia and Pennsylvania.

1913 Some field experiments with the chestnut canker fungus. Phytopath. **3**:73.
Abstract of paper read before the American Phytopathological Society, January, 1913. Inoculation experiments. Author finds that drought does not alter susceptibility of the tree.

1914 Field studies on the Endothia canker of chestnuts in New York State. Phytopath. **4**:—. (In press.)
Records field experiments with regard to the life history of the fungus and its distribution in New York State.

Rehm, H.

1907 Ascomycetes exs. Fasc. 39. Ann. myc. **5**:210.
Regards the chestnut fungus as one of the Hypocreaceae, and proposes the combination *Valsonectria parasitica* (Murrill) Rehm.

Ruggles, A. G.

1913 Notes on a chestnut-tree insect. Science **38**:852.
Discusses life history of the bark insect commonly known as the bast-miner and previously erroneously referred to by Metcalf and Collins (1911) as *Agrilus bilineatus;* believes this insect has an important bearing on the spread of *Endothia parasitica.*

Shear, C. L.

1912 a The chestnut bark fungus, Diaporthe parasitica. Phytopath. **2**:88–89.
Reports that *Endothia radicalis* (Schw.) and *Diaporthe parasitica* Murr. are distinct.

1912 b The chestnut blight fungus. Phytopath. **2**:211–212.
States that the European *Endothia radicalis* is identical with *Diaporthe parasitica* Murr., and that it was probably introduced into America from Europe.

1913 a Endothia radicalis (Schw.). Phytopath. **3**:61.
Author retracts his former statement, and now believes that *E. radicalis* (Schw.) is not the linear-spored form but the narrowly-oval-spored form, *E. virginiana* Anders.; does not now believe that the blight fungus was introduced from Europe.

1913 b The type of Sphaeria radicalis Schw. Phytopath. **3**:191–192.
Examines Fries's type specimen of *S. radicalis*, and decides that it is identical with the form called *E. gyrosa* by Clinton and *E. virginiana* by the Andersons.

Shear, C. L., and Stevens, N. E.

1913 a Cultural characters of the chestnut-blight fungus and its near relatives. U. S. Plant Indus. Bur. Circ. 131:3–18.
Describe in detail cultural studies of all the American species of Endothia, and consider *E. parasitica* as a distinct species.

1913 b The chestnut-blight parasite (Endothia parasitica) from China. Science **38**:295–297.
Give cultural and inoculation experiments proving that the fungus collected in China is identical with *Endothia parasitica.*

Spaulding, P.

1912 Notes upon tree diseases in the eastern States. Mycologia 4:148–149.

Gives the distribution of the disease in Maryland, and advocates the cutting-out method.

Stewart, F. C.

1912 Can the chestnut bark disease be controlled? Pennsylvania Chestnut Blight Conference. Stenographic rept., p. 40–45. Harrisburg, 1912.

Author discusses his views of the impracticability of the cutting-out method.

Stoddard, E. M., and Moss, A. E.

1913 The chestnut bark disease. Connecticut Agr. Exp. Sta. Bul. 178:1–19.

A bulletin of general information.

Stone, G. E.

1911 The chestnut disease (Diaporthe parasitica). Massachusetts Agr. Exp. Sta. Report of the Botanist, Ann. rept. 23:24–25.

Gives distribution in Massachusetts; believes the disease is favored by weakness of the trees produced by unfavorable weather conditions.

Studhalter, R. A.

1914 Insects as carriers of the chestnut blight fungus. Phytopath. 4:52.

Abstract of paper read before the American Phytopathological Society, December, 1913. Author finds spores on twenty-four out of seventy-five insects taken from diseased trees.

Walton, R. C.

1914 The relation of temperature to the expulsion of ascospores of Endothia parasitica. Phytopath. 4:52.

Abstract of paper read before American Phytopathological Society, December, 1913. No ascospore ejection during the winter of 1912–1913; laboratory tests show that ejection is dependent on temperature.

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A BIBLIOGRAPHY OF THE WRITINGS OF PROFESSOR MARK VERNON SLINGERLAND

By M. D. LEONARD

ITHACA, NEW YORK
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M. V. Slingerland

PROFESSOR MARK VERNON SLINGERLAND

Professor Slingerland, a list of whose scientific writings follows, played a very important part in the more recent development of economic entomology in this country — that development which followed the establishment of the federal agricultural experiment stations. He was one of that large group of young men who found opportunities to devote themselves to scientific work through the establishment of these stations, and who by their efforts have proved the wisdom of such govermental aid to agriculture.

Professor Slingerland's call to his life work came to him suddenly and with irresistible force. When he came to Cornell he knew nothing of entomology. In speaking of this fact afterward he said that when he entered the University he did not know that a butterfly was developed from a caterpillar. During his freshman year he listened to a lecture on the transformations and habits of insects, and the wonders of the insect world took such a deep hold on his imagination that he could not sleep during the following night. From that moment there was no doubt in his mind of what his life work should be.

At this time he was defraying his college expenses by taking care of the then recently erected insectary. Opportunity was soon given him to take part in the entomological work that was being conducted in this building. He proved to be so efficient in this work that while yet an undergraduate he was made Assistant Entomologist of the Experiment Station.

This appointment was made in 1890. During that year and the year following, bulletins on fruit insects and on wireworms were published jointly by the writer of this sketch and Mr. Slingerland. After the publication of these bulletins the entomological work of the experiment station was conducted almost entirely by Mr. Slingerland, and the work remained in his charge until his death.

In 1892 Mr. Slingerland completed his college course, graduating with the degree of B.S. in Agr. At this time he was given the rank of Instructor in Entomology; and in 1899 he was made Assistant Professor of Economic Entomology, which position he held until his death on March 11, 1909.

Professor Slingerland's life was an exceedingly active one. In the seventeen years that intervened between his graduation and his death, he faithfully performed the duties of a teacher and found time for researches that made for him an international reputation.

The bulletins that he published were in a marked degree monographic. Instead of writing about many insects he selected a few and discussed them thoroughly, working up as far as possible every detail in the life history of the species studied. A striking feature of Professor Slingerland's bulletins is the excellence of the illustrations; he spared neither time nor care in photographing entomological subjects, and acquired a remarkable degree of skill in this field.

Although his work is characterized by the highest degree of scientific accuracy, he never forgot that the object of his work was to aid those who till the soil. He never allowed his interests in the purely scientific aspects of the subjects studied to cause him to neglect the practical applications of the results obtained. A marked instance of this was his invention of the Spray Calendar; for he devised the first tabular calendar arrangement of spraying suggestions. This was printed and used at farmers' institutes in 1894. The value of this method of publication was apparent at once and the method has been generally adopted by experiment stations.

As a teacher Professor Slingerland was clear, direct, and painstaking. He had the keenest interest in the needs of each individual student. In the last conversation that the writer had with him, only a few hours before his death, he discussed the work of several of his students. Even at that hour, when it was evident to others that the end was near, his thought was not of himself but of his students.

In this manner closed the life of one who, although given but few years in which to work, accomplished much; and who endeared himself to his fellow workers by his sterling qualities as a man and a friend.

J. H. COMSTOCK

A BIBLIOGRAPHY OF THE WRITINGS OF PROFESSOR MARK VERNON SLINGERLAND

M. D. LEONARD

1890

From the egg to the cabinet. Cornell mag. **3**:68–74.

Insects injurious to fruits. By J. H. Comstock and M. V. Slingerland. Cornell Univ. Agr. Exp. Sta. Bul. 23:101–126.

1891

Wireworms. By J. H. Comstock and M. V. Slingerland. Cornell Univ. Agr. Exp. Sta. Bul. 33:191–272.

The horn fly. Cornell Univ. Agr. Exp. Sta. Bul. 37:378–381.

Still another pear pest described! Oswego daily times, June 6.
Pear-leaf blister mite and bud moth.

The hop louse. Oneida dispatch, June 6.

1892

Caterpillars. A threatened tree scourge in Rochester. Post-express [Rochester, New York], October 31.
White-marked tussock-moth.

Drasteria erichto. Ent. news **3**:63.

The bean weevil. Insect life **5**:86.

Drasteria erechtea. Insect life **5**:87.

The pear-tree psylla. Insect life **5**:100–104.

The pear-leaf blister mite. Insect life **5**:104.

The pear-tree psylla. Cornell Univ. Agr. Exp. Sta. Bul. 44:159–186.

The black peach-aphis. Cornell Univ. Agr. Exp. Sta. Bul. 49:325–331.

1893

The bud moth. Cornell Univ. Agr. Exp. Sta. Bul. 50:1–29.

The four-lined leaf-bug. Cornell Univ. Agr. Exp. Sta. Bul. 58:205–239.

The pear-leaf blister. *Phytoptus pyri*. Cornell Univ. Agr. Exp. Sta. Bul. 61:317–328.

Notes from the Cornell insectary. I. Some results of a trap lantern experiment. Can. ent. **25**:81–86, tables 1–3.

1893 (*continued*)

Notes from the Cornell insectary. II. Some observations upon plant lice. Science **21**:48–49.

Notes from the Cornell insectary. III. Some observations upon two species of Bruchus. Psyche **6**:445–449, pl. 16.
Bruchus obtectus and *B. quadrimaculatus.*

Facts about the Cornell mixture. Amer. agr. **52**:604.

The Cornell mixture. Science **22**:105–106.

A new pest to cows. New York homestead **27**:321.
The horn fly(?).

Pests and the way to exterminate them. Troy daily press, September 1.
Elm leaf-beetle.

Save the trees. Insect enemies that can now be fought effectually. Post-express [Rochester, New York], May 4.
White-marked tussock-moth.

Protect the trees. Post-express [Rochester, New York], May 5.
White-marked tussock-moth.

The caterpillar pest. Post-express [Rochester, New York], May 9.
White-marked tussock-moth.

The caterpillar pest. Post-express [Rochester, New York], May 17.
White-marked tussock-moth.

The caterpillar pest. Post-express [Rochester, New York], May 18.
Portion of above letter quoted.

Poison this peach eater. Rural New-Yorker **52**:381.
May beetles(?).

To kill insects in grain. Rural New-Yorker **52**:493.
Angoumois grain moth, Mediterranean flour moth, or Indian meal moth(?).

Benzine for the clothes moth. Rural New-Yorker **52**:509.

The " seventeen-year locust " in its hole. Rural New-Yorker **52**:509.

The wonderful winged ants. Rural New-Yorker **52**:588.

How to fight grasshoppers. Rural New-Yorker **52**:588.

Do bats bring bedbugs? Rural New-Yorker **52**:588–589.

Crawfish after all. Rural New-Yorker **52**:606.
Cambarus diogenes(?).

All about the wheat midge. Rural New-Yorker **52**:652.

Life and habits of " devil bugs." Rural New-Yorker **52**:652.
Hag-moth caterpillar.

Apple-twig borer on grapes. Rural New-Yorker **52**:685.
Amphicerus bicaudatus.

Some dangerous bark beetles. Rural New-Yorker **52**:700.
Phlœotribus liminaris.

Do bats bring bedbugs? Rural New-Yorker **52**:718.

Jaws that are tougher than hickory! Rural New-Yorker **52**:781.
Oncideres cingulata.

Two bad apple enemies. Rural New-Yorker **52**:816.
Chionaspis furfura and *Trypeta pomonella.*

1894

A talk about wireworms. Rural New-Yorker 53:68.

A bad grapevine pest. Rural New-Yorker 53:84.
Desmia funeralis.

Bees on potatoes and grapes. Rural New-Yorker 53:100.

To keep moths from wool. Rural New-Yorker 53:101.

Apple tree canker; grape beetles and bloom. Rural New-Yorker 53:151.
Graptodera chalybea.

Codling moth; hen manure for orchard. Rural New-Yorker 53:158.

Will fertilizers kill insects? Rural New-Yorker 53:184–185

The facts about nozzles and sprayers. Rural New-Yorker 53:253.

Life and death of the white grub. Rural New-Yorker 53:281.

Insect enemies of clover. Rural New-Yorker 53:281.
Hylasinus trifolii.

Buffalo tree-hopper on apples. Rural New-Yorker 53:297.

A talk about plant lice. Rural New-Yorker 53:361.

To destroy bark lice in Canada. Rural New-Yorker 53:361.
Oyster-shell bark-louse.

Oyster-shell bark-louse on apples. Rural New-Yorker 53:361.

To prevent buffalo bugs. Rural New-Yorker 53:383.

Plant lice on oats. Rural New-Yorker 53:409.
The grain aphis.

Harmless insects accused. Rural New-Yorker 53:425.
Podabrus rugulosis(?).

An insect brought from the World's Fair. Rural New-Yorker 53:425.
Angoumois grain moth.

Insects on hollyhocks. Rural New-Yorker 53:457.
Chrysomela sigmoides and *Corythuca fuscigera.*

The periodical cicada, or 17-year locust. Rural New-Yorker 53:470, 488, fig. 122.

Clover mite working on raspberries. Rural New-Yorker 53:568.
Bryobia pratensis(?).

Potato stalk insects. Rural New-Yorker 53:569.
Gortyna nitella and *Trichobaris trinotata.*

Leaf-feeding beetle; a disgusting insect. Rural New-Yorker 53:569.
Chelymorpha argus.

Insects that destroy woolen cloth. Rural New-Yorker 53:600–601.
Tineola biselliella, Tinea pellionella, and *T. tapetzella.*

A new insect in a well. Rural New-Yorker 53:617.
May-fly larva(?).

A stinging caterpillar. Rural New-Yorker 53:646, fig. 170.
Automeris io.

Chicken mites on a horse. Rural New-Yorker 53:665.

The new plum pest: the plum scale. Rural New-Yorker 53:711.
Lecanium corni.

To get rid of ants. Rural New-Yorker 53:777.

The harlequin cabbage bug in winter. Rural New-Yorker 53:793.

1894 (*continued*)

Can we poison wireworms? Rural New-Yorker **53**:809.

Night prowling peach pests. National nurseryman **2**:57–58.
Climbing cutworms.

The periodical cicada, or locust. Farmer's advocate [London, Ontario] **29**:225.

Grape vine flea beetle. Grape belt [Fredonia, New York], June 15. (Reprinted from the North East advertiser, North East, Pennsylvania, May 26, 1894.)

Bugs and things. Grape belt [Fredonia, New York], June 22.
Lecanium sp.

A new plum plague. Rochester herald, October 31.
Lecanium corni.

The bud moth and pear psylla. West. New York Hort. Soc. Proc. **39**:140–143.

[No title.] Ent. news **5**:17.
Pœcilocapsus lineatus.

The cabbage root maggot, with notes on the onion maggot and allied insects. Cornell Univ. Agr. Exp. Sta. Bul. 78:479–577.

A plum scale in western New York. Cornell Univ. Agr. Exp. Sta. Bul. 83:676–699.
Lecanium corni.

1895

Danger of spreading the San José scale. Rural New-Yorker **54**:5.

An insect fond of rhubarb. Rural New-Yorker **54**:37.
Lixus concavus.

Cocoon of a giant silkworm. Rural New-Yorker **54**:52.
Samia cecropia.

Beans "stung" by an unknown insect. Rural New-Yorker **54**:52.

Killing codling moths in winter. Rural New-Yorker **54**:52.

Do sprayed apples live longer? Rural New-Yorker **54**:69.

A katydid that did no mischief. Rural New-Yorker **54**:69, fig. 24.
Cyrtophyllus concavus.

Scurfy bark-louse on apple trees. Rural New-Yorker **54**:85.

The San José scale in Indiana. Rural New-Yorker **54**:87.

A "blight" on grape vines. Rural New-Yorker **54**:104.
Either powdery or downy mildew.

Some homemade sheep dips. Rural New-Yorker **54**:112.

Why lime is used in bordeaux mixture. Rural New-Yorker **54**:138.

Oyster-shell bark-louse on apples. Rural New-Yorker **54**:140.

Corn and cotton worms; North and South. Rural New-Yorker **54**:143.
Heliothis armiger and *Alabama argillacea.*

Knots on a mountain ash. Rural New-Yorker **54**:160.

A troublesome new plum pest. Rural New-Yorker **54**:161, fig. 54.
'hytoptus phlœocoptes.

1895 *(continued)*

What nips the plum trees? Rural New-Yorker **54**:194.
Ithycerus noveboracensis(?).

What to do for raspberry anthracnose. Rural New-Yorker **54**:220.

The white grub in strawberries and manure. Rural New-Yorker **54**:220.

A treatment for pear blight. Rural New-Yorker **54**:241.

A white mould on carrots. Rural New-Yorker **54**:243.

Is there a cure for plant lice? Rural New-Yorker **54**:254.

The rust of the quince. Rural New-Yorker **54**:254.

Latest news on the plum scale. Rural New-Yorker **54**:260, fig. 83.

Habits of squash-vine borers. Rural New-Yorker **54**:261.

The apple maggot "*Trypeta pomonella.*" Rural New-Yorker **54**:280.

Spots on a pear tree. Rural New-Yorker **54**:280.
Natural to the bark.

Galls that infest the mulberry. Rural New-Yorker **54**:297.
Pachypsylla celtidis-gemma, or a closely allied species(?).

A bad fruit bug. Rural New-Yorker **54**:328.
Lygus pratensis.

Disease and insects on apple twigs. Rural New-Yorker **54**:329.
Cause of the disease undetermined; insects are *Megalopye opercularis* and *Clisiocampa americana.*

Insects in stored wool. Rural New-Yorker **54**:345.

Work of the snowy tree cricket. Rural New-Yorker **54**:345.

The Norfolk Island pine coccus or bark-louse. Rural New-Yorker **54**:345.
Rhizococcus araucariæ.

"Dungworms" are wanted. Rural New-Yorker **54**:345.
White grubs(?).

Work of the bud-moth. Rural New-Yorker **54**:361.

Washing or spraying plum trees. Rural New-Yorker **54**:361.

A new raspberry eater. Rural New-Yorker **54**:377.
Typophorus canellus.

Scale insects on the pine. Rural New-Yorker **54**:377.
Chionaspis pinifoliæ.

"Black spot" on the peach. Rural New-Yorker **54**:377.

Life history of plant lice. Rural New-Yorker **54**:377.

Insects on Georgia melons. Rural New-Yorker **54**:392–393.
Diabrotica vittata and *D. duodecimpunctata.*

The woolly aphis on Kansas apples. Rural New-Yorker **54**:393.

Salt for the peach borer? Rural New-Yorker **54**:393.

A "die back" caused by a freeze. Rural New-Yorker **54**:393.

[No title.] Rural New Yorker **54**:397.
An article relating to the addition of lime to paris green.

To kill the cabbage worm. Rural New-Yorker **54**:408.

What to do for "chestnut worms." Rural New-Yorker **54**:408.

Cut worms and green currant worms. Rural New-Yorker **54**:409.

1895 *(continued)*

A new apple pest. Rural New-Yorker **54**:425, fig. 136.
Corythuca arcuata (?).

Some worms and webs. Rural New-Yorker **54**:425.
Either the imported currant borer moth or the American currant borer beetle(?), and *Nematus ventricosus.*

A case of "die back." Rural New-Yorker **54**:425.
Epicærus imbricatus.

Terrible tales of a "worm." Rural New-Yorker **54**:441.
Millipedes.

The plum curculio on apples. Rural New-Yorker **54**:457.

A talk about squash bugs. Rural New-Yorker **54**:473.

The life story of a worm. Rural New-Yorker **54**:502, fig. 157.
Phlegothonthius.

A trio of bugs. Rural New-Yorker **54**:505.
Lygus pratensis, Crepidodera cucumeris, and another probably allied to the rose leaf-hopper.

An ash borer; the rhinocerus beetle. Rural New-Yorker **54**:521.
The former is probably *Podosesia syringæ.*

A grape vine leaf eater. Rural New-Yorker **54**:521.
Procris (Harrisina) americana.

Another omnivorous insect pest. Rural New-Yorker **54**:521.
Otiorynchus ovatus.

Something about "pear blight." Rural New-Yorker **54**:537.

The queen of the night. Rural New-Yorker **54**:553, fig. 171.
Tropæa luna.

Why do pears crack? Rural New-Yorker **54**:553.
Pear leaf blight.

The "old-fashioned" potato bug. Rural New-Yorker **54**:569, fig. 180.
Epicauta vittata.

A bug that frightens hens. Rural New-Yorker **54**:569.
Sand cricket.

[No title.] Rural New-Yorker **54**:573.
Curling of potato leaves due, possibly, to some insect injury.

The shot-hole borer. Rural New-Yorker **54**:585, fig. 183.

Wireworms again; sour land. Rural New-Yorker **54**:601.

An anti-ant remedy wanted. Rural New-Yorker **54**:601.

White grubs in corn. Rural New-Yorker **54**:601.

A borer in cedar wood. Rural New-Yorker **54**:617.
Undetermined.

Another blister beetle. Rural New-Yorker **54**:617.
Epicauta pennsylvanica.

The "live-forever" disease. Rural New-Yorker **54**:632.
Vermicularia telephii (?).

Treatment for celery blight. Rural New-Yorker **54**:632.

Ants as a fertilizer. Rural New-Yorker **54**:632.

Various bad bugs. Rural New-Yorker **54**:649.
Pontia rapæ and *Murgantia histrionica.*

1895 *(continued)*

The blackberry leaf-spot fungus. Rural New-Yorker **54**:665.
Septoria rubi(?).

A bug with a long snout. Rural New-Yorker **54**:665.
Balaninus quercus.

The pests of the hen house. Rural New-Yorker **54**:679, fig. 215.
Menopon pallidum and *Dermanyssus gallinæ.*

Copper solution for celery blight. Rural New-Yorker **54**:681.

The troublesome harlequin bug. Rural New-Yorker **54**:697.

Will salt kill grubs and worms? Rural New-Yorker **54**:713.

A liquid " thistle destroyer." Rural New-Yorker **54**:777.

Bugs, mustard seed, and clover. Rural New-Yorker **54**:777.
Grain plant louse(?).

The story of the apple rust. Rural New-Yorker **54**:841.

Work of the snowy tree cricket. Rural New-Yorker **54**:856.

The magnolia-blossom tortricid. Ent. news **6**:175.

A curious hammock and its maker. Ent. news **7**:109.

A new plum pest. West. New York Hort. Soc. Proc. **40**:32–43.
Lecanium corni.

Fir sawfly. Amer. agr. **56**:285.
Lophyrus abietis.

[No title.] Cornell Univ. Agr. Exp. Sta. No date.
A spray calendar, published in 1894. (See Cornell Univ. Agr. Exp. Sta. Bul. 252:335.)

The cigar-case-bearer in western New York. Cornell Univ. Agr. Exp. Sta. Bul. 93:211–230.

Climbing cutworms in western New York. Cornell Univ. Agr. Exp. Sta. Bul. 104:551–600.

Feltia subgothica, Haworth, or Agrotis (Subgen. Agronoma) jaculifera, Guenee, which? Can. ent. **27**:301–308, pl.

The plum-twig gall-mite. Can. ent. **27**:329.

The clover root borer. Country gentleman **40**:208–209.

An important new book. Ithaca daily journal, April 9.
Review of " A manual for the study of insects," by John Henry Comstock and Anna Botsford Comstock.

[No title.] Oswego daily palladium, June 1.
Lepisma saccharina.

Plum scale in Michigan. Allegan gazette, June 22.
Lecanium corni.

A rare species. Waverly free press, September 21.
Phobetron pithecium.

1896

Wireworms and the bud moth. Cornell Univ. Agr. Exp. Sta. Bul. 107:33–66.

The pear psylla and the New York plum scale. Cornell Univ. Agr. Exp. Sta. Bul. 108:67–86.

1896 (*continued*)

Green fruit worms. Cornell Univ. Agr. Exp. Sta. Bul. 123:505–522.
Entomology. West. New York Hort. Soc. Proc. **41**:18–23.
Some "dung worms" examined. Rural New-Yorker **55**:2, fig. 2.
Aphodius fimetarius.
The apple crop and 17-year locusts. Rural New-Yorker **55**:53.
Can we starve the white grubs? Rural New-Yorker **55**:69.
How to fleece fleas of life. Rural New-Yorker **55**:99.
How to fight the tarnished plant-bug. Rural New-Yorker **55**:99.
What will kill lice? Rural New-Yorker **55**:100.
How to fight white grubs. Rural New-Yorker **55**:116.
What can be done for wireworms? Rural New-Yorker **55**:117.
Some notes on celery blight. Rural New-Yorker **55**:118.
A colony of "spring-tails" in water. Rural New-Yorker **55**:138.
The snowy tree cricket on raspberries. Rural New-Yorker **55**:157, fig. 57.
Cause and prevention of oat smut. Rural New-Yorker **55**:197.
"Tumble bugs" and their curious habits. Rural New-Yorker **55**:236, fig. 76.
The scurfy bark louse. Rural New-Yorker **55**:236.
Salt and lime for onion maggots. Rural New-Yorker **55**:257.
How to fight the canker worm. Rural New-Yorker **55**:288.
The use of bordeaux mixture; sulphate of copper. Rural New-Yorker **55**:288.
The painted hickory borer. Rural New-Yorker **55**:303.
Cyllene pictus.
Plant traps for cabbage insects. Rural New-Yorker **55**:303.
A melon disease; bordeaux mixture. Rural New-Yorker **55**:315.
"Damping-off" fungus(?).
How to kill cabbage insects. Rural New-Yorker **55**:320.
Crickets as strawberry pickers. Rural New-Yorker **55**:320.
The chinch bug in New York State. Rural New-Yorker **55**:337.
On what do 17-year cicadas live? Rural New-Yorker **55**:351.
A group of insect depredators. A case of rusted wheat. Printers' ink on trees. The oyster-shell bark-louse. To drive flies out of stables. What will kill root lice? Use of bordeaux mixture on apples. Rural New-Yorker **55**:352.
Rust in the blackberry. Rural New-Yorker **55**:353.
Destroying the codling moth without spraying. Rural New-Yorker **55**:357.
More light turned on white grubs. Rural New-Yorker **55**:369, fig. 119.
"Fighting canker worms." Rural New-Yorker **55**:371.
Root gall in peach trees. Rural New-Yorker **55**:385, fig. 128.
Propagating the lady-bird beetle. Rural New-Yorker **55**:385.

1896 (*continued*)

A new destructive insect on pecans. Rural New-Yorker 55:401, fig. 133.

Fighting insect foes. Sulphur as an insecticide. How to kill "June bugs." Lye in place of lime for bordeaux mixture. The troublesome umbrella ant. Rural New-Yorker 55:416.

The white grub question. Rural New-Yorker 55:418.

Grape-vine tomato-gall; poison ivy. Rural New-Yorker 55:433.
Lasioptera vitis.

Insects found on grapes. Rural New-Yorker 55:448.
Katydid and praying mantis.

Insects that work on strawberries. Rural New-Yorker 55:448.
Phoxopteris comptana.

Insect and fungous foes of fruit. Rose beetles; a new apple pest. [Green fruit worms(?).] More about dung worms. "Plum rot." What is it? How cure it? Seventeen-year locusts not poisonous. Twig blight and apple rust. Rural New-Yorker 55:464.

A lecture on cutworms. Rural New-Yorker 55:480, fig. 156.

A swarm of business bees. Rural New-Yorker 55:481.

The army worm does battle. Rural New-Yorker 55:495, fig. 158.

The oyster-shell bark-louse. Rural New-Yorker 55:496, fig. 159.

A worm that picks blueberries. Rural New-Yorker 55:497, fig. 160.
Diastictus inceptaria.

The harlequin bug, or calico-back. Rural New-Yorker 55:513.

Anthracnose of the raspberry. Rural New-Yorker 55:513.

The "old fashioned" potato beetle. Rural New-Yorker 55:529.

Dendrolene for borers. Rural New-Yorker 55:529.

A number of insects and diseases. Rural New-Yorker 55:545.

Borers in fruit and shade trees. "Raupenleim" and "dendrolene." Rural New-Yorker 55:556.

The "white blast" in onions. Rural New-Yorker 55:561.
Thrips tabaci.

Potato beetles on tomato vines. Rural New-Yorker 55:576.

The carpet beetle. Rural New-Yorker 55:582, figs. 180, 181.

Life history of the apple rust. Rural New-Yorker 55:609.

The harlequin cabbage bug. Rural New-Yorker 55:609, fig. 192.

Some insects and fungous depredators. Swelling at the end of twigs. Spotted plums; cultivating orchards. [Plum curculio (?).] The fiery hunter and its work. White grubs in strawberries. Pear blight and plum rots. Rural New-Yorker 55:672–673.

Insects that bother the fruit grower. Habits of the strawberry root-worm. The grape vine leaf-hopper. An attack of canker worms. Rural New-Yorker 55:689.

A grasshopper's snake story. Rural New-Yorker 55:697, fig. 220.

1896 (*continued*)

Life history of the grape phylloxera. Rural New-Yorker **55**:704, fig. 229.

Weevil eaten wheat as food. Rural New-Yorker **55**:704.

The biography of a bedbug. Rural New-Yorker **55**:742, fig. 239; 758, 774.

Habits of the cranberry fruit worm. Rural New-Yorker **55**:753.

White arsenic in place of paris green. Rural New-Yorker **55**:769.

The scurfy bark-lice on apples. Rural New-Yorker **55**:784.

The life of the peach borer. Rural New-Yorker **55**:800.

"Worms" that ruin quinces. Rural New-Yorker **55**:816.
Conotrachelus cratægi.

Next season's crop of army worms. Rural New-Yorker **55**:846.

Winter work among fruit insects. Amer. agr. **57**:58.

Winter work among insects injurious to fruits. Garden and forest **9**:36.

What is the elm tree worm? Ithaca daily journal, June 22.

The grape pest in Wisconsin vineyards. Fruit **8**:8.
Amphicerus bicaudatus.

Recent work among the insect foes of the horticulturist. Michigan fruit grower and practical farmer **5**:8.

The Agrotis subgothica of Haworth, again. Can. ent. **28**:295–299, pl. 4.

Report of the Entomologist. Cornell Univ. Agr. Exp. Sta. Ann. rept. **8** for 1895:16–17.

1897

The pistol-case-bearer in western New York. Cornell Univ. Agr. Exp. Sta. Bul. 124:1–17.

The currant-stem girdler and the raspberry-cane maggot. Cornell Univ. Agr. Exp. Sta. Bul. 126:39–60.

The army worm in New York. Cornell Univ. Agr. Exp. Sta. Bul. 133:231–258.

Various washes for fruit trees. Rural New-Yorker **56**:69.

What treatment for strawberry rust? Rural New-Yorker **56**:99.

Sulphate of iron for spraying. Rural New-Yorker **56**:115.

Some facts about the codling moth. Rural New-Yorker **56**:115.

To kill lice on a horse. Rural New-Yorker **56**:166.

Worms in soil; plum borers. Rural New-Yorker **56**:175.
Wireworms and angleworms; borers undetermined.

How to make and use bordeaux mixture. Rural New-Yorker **56**:208.

The strawberry leaf-roller. Rural New-Yorker **56**:223.

Apple trees least susceptible to borers. Rural New-Yorker **56**:223.

Protection against borers. Rural New-Yorker **56**:223.
Apple borer.

Inoculating trees to kill insects. Rural New-Yorker **56**:241.

1897 (*continued*)

Plant lice on gooseberries. Rural New-Yorker **56**:242.
Currant plant-louse.

Pine tar on apple trees. Rural New-Yorker **56**:260.

The scurfy bark-louse on apple trees. Rural New-Yorker **56**:260.

What is onion smut? Rural New-Yorker **56**:275.

The cost of spraying grapes. Rural New-Yorker **56**:277.

Life habits of twig borers. Rural New-Yorker **56**:293.
Amphicerus bicaudatus.

Lime and salt for oat smut. Rural New-Yorker **56**:293.

All about whale-oil soap. Rural New-Yorker **56**:308.

Katydid "didn't do a thing" to the twigs. Rural New-Yorker **56**:309, fig. 133.

"Black lice" on apple trees. Rural New-Yorker **56**:309.
Apple aphis(?).

The oyster-shell bark-louse. Rural New-Yorker **56**:309.

Onion thrips on Long Island. Rural New-Yorker **56**:309.

"Root lice" on apple trees. Rural New-Yorker **56**:323.

Canker worms in Kansas. Rural New-Yorker **56**:324.

Roofing paint for painting trees. Rural New-Yorker **56**:324.

Life history of the plum curculio. Rural New-Yorker **56**:354, fig. 156.

Great danger from San José scale. Rural New-Yorker **56**:356.

The dangerous strawberry weevil. Rural New-Yorker **56**:372.

What is "pure paris-green"? Rural New-Yorker **56**:372.

Life and work of the pear slug. Rural New-Yorker **56**:389, fig. 170.

A patent "tree wash." Rural New-Yorker **56**:389.

Killing the horn fly. Rural New-Yorker **56**:398.

Calomel for pear blight. Rural New-Yorker **56**:405.

Insects in cow peas; melon disease. Rural New-Yorker **56**:405.
Southern pea weevil, *Bruchus chinensis.*

The grape-vine flea-beetle. Rural New-Yorker **56**:420.

Lice on plum and apple trees. Rural New-Yorker **56**:420.
Apple aphis and other species mentioned.

Plum curculio and its eggs. Rural New-Yorker **56**:420.

"Fire blight" on apple trees. Rural New-Yorker **56**:437.

Do 17-year locusts damage fruit trees? Rural New-Yorker **56**:437.

Rusts on blackberries and raspberries. Rural New-Yorker **56**:453.
Orange or red rust.

Galls on grape vines. Rural New-Yorker **56**:453.
Grapevine tomato gall.

The cottony maple scale. Rural New-Yorker **56**:485.

A new blight on plums. Rural New-Yorker **56**:485.
Cause undetermined.

"Gold bugs" on sweet potatoes. Rural New-Yorker **56**:485.
Coptocycla aurichalcea.

1897 *(continued)*

Thorough cultivation and potato bugs. Rural New-Yorker **56**:485.

The gypsy moths in New York State. Rural New-Yorker **56**:499.
Proved to be *Clisiocampa disstria.*

The predaceous diving beetle. Rural New-Yorker **56**:501, fig. 208.
Dytiscus sp.

The San José scale at Cornell. Rural New-Yorker **56**:515.

Life history of the silk worm. Rural New-Yorker **56**:529, fig. 214.

Pear psylla and lice on maples. Rural New-Yorker **56**:537.

The clover mite and fruit. Rural New-Yorker **56**:537.

The melon and cucumber borers. Rural New-Yorker **56**:548, fig. 226.
Endioptis nitidalis and *E. hyalinata.*

Will bordeaux mixture retain its strength? Rural New-Yorker **56**:548.

What is "yellows" in the peach? Rural New-Yorker **56**:580.

A corn-eating maggot. Rural New-Yorker **56**:596.
Phorbia fuscıceps.

Any better fungicide than bordeaux mixture? Rural New-Yorker **56**:661.

Destroying a wasp's nest. Rural New-Yorker **56**:676.

The chinch bug in New York State. Rural New-Yorker **56**:684.

The story of the bumble bee. Rural New-Yorker **56**:692.

Possibly a formidable enemy of crimson clover. Rural New-Yorker **56**:694.
Polythrincium trifolii.

Pomace flies hard to kill. Rural New-Yorker **56**:709.

A chapter on wireworms. Rural New-Yorker **56**:725.

Fight the San José scale this fall. Rural New-Yorker **56**:740.

Life changes of the peach borer. Rural New-Yorker **56**:805.

Green lice on cabbage. Rural New-Yorker **56**:805.
Cabbage aphis and cucumber aphis.

The work of angle worms. Rural New-Yorker **56**:818.

Will the army worm come this year? Amer. agr. **59**:582.

A new destructive beetle. Practical farmer, May 15.
Anomala undulata. Letter quoted.

Hair worms or hair snakes. Jamestown evening journal, June 16.

The squash destroyer. Tioga county herald [Newark Valley, New York], July 16.
Anasa tristis.

Pigeon horn tail — *Tremex columba.* Madison county leader [Morrisville, New York], September 30.

The crinkled flannel moth (*Megalopyge crispata*, Pack.). Can. ent. **29**:1–2, pl. 1.

The blueberry span-worm (*Diastictis inceptaria*, Walk.) and the bumble flower-beetle (*Euphoria inda*, Linn.). Can. ent. **29**:49–52, pl. 3.

The columbine borer (*Hydroecia purpurifascia*, G. & R.). Can. ent. **29**:161–162, pl. 6.

1897 (*continued*)

The raspberry-cane maggot (*Phorbia rubivora*, Coquillett). Can. ent. **29**:162–163.

Fruit pests. Orleans American [Albion, New York], December 2.
Lime-tree winter moth and fall cankerworm.

Entomology. West. New York Hort. Soc. Proc. **42**:22–31.

Report of the Entomologist. Cornell Univ. Agr. Exp. Sta. Ann. rept. **9** for 1896:26–28.

1898

The codling moth. Cornell Univ. Agr. Exp. Sta. Bul. 142:1–69.
Яблочная плодожорка. A translation, with additions, of the above, by S. A. Mokshetsky. Published at Simferopol, Russia, in 1902.

Report of progress in the entomological division. Cornell Univ. Agr. Exp. Sta. Bul. 146:641–642.

The quince curculio. Cornell Univ. Agr. Exp. Sta. Bul. 148:691–715.

The grape-vine flea-beetle. Cornell Univ. Agr. Exp. Sta. Bul. 157: 185–213.

Bisulphide of carbon for peach borers. Not recommended for the East. Rural New-Yorker **57**:34.

Club root in the cabbage. Rural New-Yorker **57**:53.

What to do for "blackberry curl." Rural New-Yorker **57**:83.
Trioza tripunctata.

What to do for woolly aphis. Rural New-Yorker **57**:84.

Bisulphide of carbon for melon lice. Rural New-Yorker **57**:121.
Melon aphis.

The bug doctor's prescriptions. Galls on tree roots. [Cause undetermined.] Spraying trees with muriate of potash. Trapping the codling moth. Heading off climbing insects. Rural New-Yorker **57**:160.

A dip for the San José scale. Rural New-Yorker **57**:180, fig. 82.

Kill the codling moths in the cellar. Rural New-Yorker **57**:221.

The powder-post and its work. Rural New-Yorker **57**:240, fig. 180.
Lyctus unipunctatus.

To prevent canker worms from crawling. Rural New-Yorker **57**:240.

The tobacco worm; a curious mistake. Rural New-Yorker **57**:281.
Phlegothontius celeus.

Facts about plant lice. Rural New-Yorker **57**:301.

A disease of apple trees. Rural New-Yorker **57**:301.
Oedema of apple trees.

The oyster-shell bark-louse. Rural New-Yorker **57**:321.

Mixing kerosene emulsion and bordeaux mixture. Rural New-Yorker **57**:336.

Insect enemies of potato beetles. Rural New-Yorker **57**:353, fig. 154.

The farm value of the crow. Rural New-Yorker **57**:384.

1898 *(continued)*

How to fight the apple borer. Rural New-Yorker **57**:385.

The grape leaf-hopper. Rural New-Yorker **57**:401.

Fighting the pear psylla. Rural New-Yorker **57**:417.

The snowy tree cricket. Rural New-Yorker **57**:417.

The steely beetle on grape vines. Rural New-Yorker **57**:448.
Grapevine flea-beetle.

Peach leaf-curl and pear blister-mite. Rural New-Yorker **57**:455, fig. 209.

The Colorado potato beetle abroad. Rural New-Yorker **57**:495.

Biting and sucking insects. Rural New-Yorker **57**:496.
Black cherry aphis.

A strange insect; the fish-moth. Rural New-Yorker **57**:496.

Wheats and wheat rusts. Rural New-Yorker **57**:513.

" Goldbugs " on sweet potatoes. Rural New-Yorker **57**:561.
Coptocycla aurichalcea.

What katydid doesn't do. Rural New-Yorker **57**:561, fig. 261.

The potato-stalk weevil. Rural New-Yorker **57**:593.
Trichobaris trinotata.

The shot-hole fungus in plums. Rural New-Yorker **57**:609.

Gasoline and clothes moths. Rural New-Yorker **57**:630.

Scale insects on California fruit. Rural New-Yorker **57**:640.
Aspidiotus aurantii and *A. perniciosus.*

How to handle the harlequin bug. Rural New-Yorker **57**:656.

How the curculio mounts plum trees. Rural New-Yorker **57**:656.

Mites that are mighty troublesome. Rural New-Yorker **57**:689.
Red spider.

Mites on a chestnut leaf. Rural New-Yorker **57**:689.

An insect in blackberry canes. Rural New-Yorker **57**:705.
Bembecia marginata(?).

Insects in stored grain. Rural New-Yorker **57**:705.

Fungous disease on gooseberries. Rural New-Yorker **57**:705.

A " sure cure " for curl leaf. Rural New-Yorker **57**:722.

Killing mealy bugs under glass. Rural New-Yorker **57**:753.

A worm that " has worms." Rural New-Yorker **57**:785.
Tomato worm and parasites.

The grain moth in wheat. Rural New-Yorker **57**:817.
Gelechia cerealella.

A tape worm in a cat. Rural New-Yorker **57**:881.
Tænia crassicollis.

Forest tree caterpillars. Watertown daily times, June 15.
Apple tent-caterpillar.

Report of the Entomologist. Cornell Univ. Agr. Exp. Sta. Ann. rept. **10** for 1897:xxi–xxiii.

Report of the Entomologist. Cornell Univ. Agr. Exp. Sta. Ann. rept. **11** for 1898:x–xii.

1898 (*continued*)

Obituary notice of Dr. Joseph Albert Lintner. Can. ent. **30**:165–166.
The pear psylla. East. New York hort. **1**.6.
Entomology. West. New York Hort. Soc. Proc. **43**:11–23.
Some new notions about some old insects. Boston transcript, February 12.

1899

Report of the Entomologist. Cornell Univ. Agr. Exp. Sta. Ann. rept. **12** for 1899:xiii–xv.
Emergency report on tent caterpillars. Cornell Univ. Agr. Exp. Sta. Bul. 170:553–564.
The cherry fruit fly, a new cherry pest. Cornell Univ. Agr. Exp. Sta. Bul. 172:21–41.
The peach-tree borer. Cornell Univ. Agr. Exp. Sta. Bul. 176:155–233.
Same. An abridged edition, p. 1–16.
A new popular name for *Clisiocampa disstria*. Can. ent. **32**:27–28.
Occurrence of *Stagmomantis carolina* in New York. Ent. news **10**:288–289.
Insects that like whiskey. Rural New-Yorker **58**:38.
How insects spend the winter. Rural New-Yorker **58**:55, 116.
Do angleworms injure soil. Rural New-Yorker **58**:157.
Ants on apple trees. Rural New-Yorker **58**:202.
Peach borer; kerosene and water. Rural New-Yorker **58**:222.
The currant fruit worm. Rural New-Yorker **58**:222.
Cheap substitutes for paris green. Rural New-Yorker **58**:231.
Same. Amer. agr. **63**:479.
Some insect questions. Rural New-Yorker **58**:262.
Bordeaux mixture in a tin cup. Rural New-Yorker **58**:283.
Scurfy bark-louse on apple. Rural New-Yorker **58**:283.
Fighting the pear slug. Rural New-Yorker **58**:302.
Killing "wiggle-tails" and ants. Rural New-Yorker **58**:302.
Making arsenite of lime. Rural New-Yorker **58**:322.
Killing plant lice in a greenhouse. Rural New-Yorker **58**:342.
Lizards in a spring. Rural New-Yorker **58**:342.
Green lice on apple trees. Rural New-Yorker **58**:361.
Work of buffalo tree-hoppers. Rural New-Yorker **58**:362.
Various bugs. Rural New-Yorker **58**:382.
Drippings from poisonous mixtures. Rural New-Yorker **58**:417.
The strawberry crown-borer. Rural New-Yorker **58**:433.
The tent caterpillar; spraying in bloom. Rural New-Yorker **58**:449.
Music and caterpillars. Rural New-Yorker **58**:479.
Tobacco and potato beetles. Rural New-Yorker **58**:527.
Cold and San José scale. Rural New-Yorker **58**:544.

1899 (*continued*)

A blister beetle. Rural New-Yorker **58**:560.
Epicauta cinerea.

The pear blister-mite. Rural New-Yorker **58**:592.

A picture of the kissing bug. Rural New-Yorker **58**:605, fig. 228.

Tent caterpillars in traps. Rural New-Yorker **58**:622.

Killing forest caterpillars. Rural New-Yorker **58**:624.

How to kill black ants. Rural New-Yorker **58**:624.

Ants and a pear tree. Rural New-Yorker **58**:641.

Killing ants in the soil. Rural New-Yorker **58**:641.

A new cherry pest. Rural New-Yorker **58**:654, fig. 244.
Rhagoletis cingulata.

Cheap and easy spraying. Rural New-Yorker **58**:672.

Is the honey bee a benefactor? Rural New-Yorker **58**:749–750, fig. 273.

The troublesome white grub. Rural New-Yorker **58**:831.

Do bees fertilize fruit? Rural New-Yorker **58**.883.

Insect pests of 1898. West. New York Hort. Soc. Proc. **44**:71–75.

The enemies of potatoes and how to combat them. Amer. agr. **63**:612, 7 figs.

Some new notions about some old insects. Massachusetts Hort. Soc. Trans. **1898**: 1:63–79.

Real kissing bug. Illus. Buffalo express [Buffalo, New York], September 3, p. 8.

Applied photography in economic entomology. Photogram **6**:141.

1900

The grape root worm, a new grape pest in New York. Cornell Univ. Agr. Exp. Sta. Bul. 184:17–32.

The common European praying mantis, a new beneficial insect in America. Cornell Univ. Agr. Exp. Sta. Bul. 185:33–47.

Some insect experiences of 1899. West New York Hort. Soc. Proc. **45**:49–52.

Something new in potato bugs. Waverly free press [Waverly, New York], July 28.
Epicauta vittata.

Possibilities of injuries to young orchards by "17-year locusts." Tree breeder **1**, October 6.

Mosquitoes of the United States. Science **12**:560–562.
Review of Bul. 25 of U. S. Bur. Ent., by L. O. Howard.

New injurious insects and remedies. East. New York Hort. Soc. Proc. **4**:55–59.

Report of the Entomologist. Cornell Univ. Agr. Exp. Sta. Ann. rept. **13** for 1900:xii–xiii.

The bee, the grape, the fact. Rural New-Yorker **59**:35, fig. 14.

1900 (*continued*)

An insect that knows beans. Rural New-Yorker 59:35.
Bruchus obtectus.

Shall we tap maple trees? Work of the caterpillars. Rural New-Yorker 59:103.
Forest tent-caterpillar.

Oyster-shell bark-louse. Rural New-Yorker 59:106.

Life of the bean weevil. Rural New-Yorker 59:123.

The English sparrow. Rural New-Yorker 59:184.

Killing the woolly aphis. Rural New-Yorker 59:203.

Compressed air sprayers. Rural New-Yorker 59:244.

Kerosene in whitewash. Rural New-Yorker 59:266.

Substitutes for paris green. Rural New-Yorker 59:275.

Scales on house plants. Rural New-Yorker 59:284.
Lecanium sp.

Formaldehyde gas for potatoes. Rural New-Yorker 59:285.

Using the bordeaux mixture. Rural New-Yorker 59:286.

Ant-hills for manure. Rural New-Yorker 59:302.

A bug-like twig. Rural New-Yorker 59:318, fig. 95.
Mechanical tissue.

Facts about the codling-moth. Rural New-Yorker 59:318.

A spray for gooseberries. Rural New-Yorker 59:320.

Combinations of insecticides. Rural New-Yorker 59:350.

The raspberry cane borer and asparagus fly. Rural New-Yorker 59:352.
The latter one of the asparagus beetles(?).

More about bordeaux mixture. Rural New-Yorker 59:352.

Ants in a dooryard. Rural New-Yorker 59:368.

Sulphur for curing trees. Rural New-Yorker 59:368.

Fighting the melon louse. Rural New-Yorker 59:432.

A "cutworm lion." Rural New-Yorker 59:433.
Undetermined ground beetle larva.

Woolly aphis. Rural New-Yorker 59:448.

Fighting the tomato worm. Rural New-Yorker 59:448.

Fighting the red spider. Rural New-Yorker 59:464.

Killing flies in stable. Rural New-Yorker 59:480.

Cleansing sprayer. Rural New-Yorker 59:480.

Potato beetles slow to hatch. Rural New-Yorker 59:496.

A new strawberry pest. Rural New-Yorker 59:526, fig. 181–182.
Harpalus caliginosus and *H. pennsylvanicus.*

Insects that eat potato beetles. Rural New-Yorker 59:542.
Perillus circumcinctus.

Insects in potato stems. Rural New-Yorker 59:544.
Trichobaris trinotata.

Rust on crab apple. Rural New-Yorker 59:561.
Cedar rust.

1900 (*continued*)

The destructive hessian fly. Rural New-Yorker **59**: 573, fig. 197–199.

An insect that saws wood. Rural New-Yorker **59**. 606.
Oncideres cingulatus (?)

Insects on gladiolus and heliotrope. Rural New-Yorker **59**: 608.
Blister beetles and *Chauliognathus pennsylvanicus*.

Bisulphide of carbon and strawberries. Rural New-Yorker **59**: 624, fig. 227.

San José scale on pears. Rural New-Yorker **59**: 672, fig. 250.

How to kill crows. Rural New-Yorker **59**: 672.

Crude petroleum for San José scale. Rural New-Yorker **59**: 733.

Do bees injure fruit? Rural New-Yorker **59**: 749.

Tar and kerosene for trees. Rural New-Yorker **59**: 784.

Bats and bedbugs. Rural New-Yorker **59**: 801.

A new hessian-fly problem. Rural New-Yorker **59**: 814.

A wonderful and interesting insect. Rural New-Yorker **59**: 846, fig. 327.
Corydalis cornutus.

1901

Insects. Insecticides. Articles in Bailey's Cyclopedia of American Horticulture **2**: 805–812.

The palmer-worm. Cornell Univ. Agr. Exp. Sta. Bul. 187: 77–101.

Three unusual strawberry pests and a greenhouse pest. Cornell Univ. Agr. Exp. Sta. Bul. 190: 141–164.

Further experiments against the peach-tree borer. Cornell Univ. Agr. Exp. Sta. Bul. 192: 189–196.

The hessian fly. Its ravages in New York in 1901. An emergency bulletin. By I. P. Roberts, M. V. Slingerland, and J. L. Stone. Cornell Univ. Agr. Exp. Sta. Bul. 194: 237–260.

Borers and their work. Tree breeder **1** (January): 8–9.

How to combat the principal enemies of the fruit-grower. Tree breeder **1** (March): 7–9.

Fall and winter work for the orchardist. Tree breeder **2**: —.

Plant lice seek new winter home. Ithaca daily news, October 15, p. 3.

Entomology. West. New York Hort. Soc. Proc. **46**: 68–73, 6 figs.

A lantern moth trap. Rural New-Yorker **60**: 35.

Strawberry "rust" and "blight." Rural New-Yorker **60**: 69.
Sphærella fragariæ.

Do curculios crawl or fly? Rural New-Yorker **60**: 104.

Black beetles on strawberry plant. Rural New-Yorker **60**: 125.

The "book worm." Rural New-Yorker **60**: 189.
Silver fish, *Lepisma saccharina.*

"Steely-bugs" and rose bugs. Rural New-Yorker **60**: 268.
On grapevines.

Fighting the plum curculio. Rural New-Yorker **60**: 289.

1901 (*continued*)

Parasites of tent caterpillars. Rural New-Yorker **60**:371, fig. 150.

The "hickory horned devil." Rural New-Yorker **60**:378, fig. 334.
Citheronia regalis.

Dung worms and white grubs. Rural New-Yorker **60**:420.

Snout beetle on fruit. Rural New-Yorker **60**:452.
Imbricated snout beetle.

An experience with spraying. Rural New-Yorker **60**:468.

Spraying for the codling moth. Rural New-Yorker **60**:468.

Scales on maple trees. Rural New-Yorker **60**:469.
Lecanium sp.

Plant lice on plum trees. Rural New-Yorker **60**:469.

Peach root-aphis. Rural New-Yorker **60**:484.

Woolly aphis on apple roots. Rural New-Yorker **60**:484.

A talk about plant lice. Rural New-Yorker **60**:484.

Seventeen-year locust; watermelon bug; strawberries. Rural New-Yorker **60**:484.

Plant lice on apples. Rural New-Yorker **60**:484.

Dodder on raspberry plants. Rural New-Yorker **60**:532.

Killing the cucumber bug. Rural New-Yorker **60**:532.
Striped cucumber-beetle.

The "bag-worm" on evergreens. Rural New-Yorker **60**: 580.

The story of plant galls. Rural New-Yorker **60**:594, fig. 262.

Some injurious lady bird insects. Rural New-Yorker **60**:610, fig. 266, 267.

Hessian flies and ragweed. Rural New-Yorker **60**:612.

Facts about "fly-proof" wheat. Rural New-Yorker **60**:627.

A mysterious bean trouble. Rural New-Yorker **60**:643, fig. 288.
Wet weather and a rot disease(?).

Crows and their food. Rural New-Yorker **60**:660.

A worm that "has worms." Rural New-Yorker **60**:674, fig. 303.
Tomato worm, *Phlegothontius* sp.

The fall webworm. Rural New-Yorker **60**:685, fig. 294–296.

Work of the 17-year locusts. Rural New-Yorker **60**:690.

A grapevine beetle. Rural New-Yorker **60**:693.
Spotted pelidnota.

Diseased caterpillars. Rural New-Yorker **60**:713.
Fall webworm.

Poultry and potato beetles. Rural New-Yorker **60**:772.

Pear leaf spot. Rural New-Yorker **60**:772.

A strange apple pest. Rural New-Yorker **60**:788.
A dry rot due to undetermined fungus.

Naphtha for grain insects. Rural New-Yorker **60**:821.

"White ants" on apple roots. Rural New-Yorker **60**:852.

Review of C. M. Weed's "Nature biographies." Country life in America **1**:xxvi–xxvii.

1902

Trap-lanterns or "moth catchers." Cornell Univ. Agr. Exp. Sta. Bul. 202:197–241.

Work of the entomological division. Cornell Univ. Agr. Exp. Sta. Bul. 206:152–153, fig. 35.

The grape root worm: further experiments and cultural suggestions. By M. V. Slingerland and John Craig. Cornell Univ. Agr. Exp. Sta. Bul. 208:173–200.

Report of the Entomologist. Cornell Univ. Agr. Exp. Sta. Ann. rept. **14** for 1901:xxiii–xxv.

Report of the Entomologist. Cornell Univ. Agr. Exp. Sta. Ann. rept. **15** for 1902:xvi–xvii.

Entomology. West. New York Hort. Soc. Proc. **47**:46–50, fig. 14, 13, 97.

Insect control. New York State Fruit Growers' Assoc. Proc. **1**.252–257.

Insects on the garden rose. Country life in America **2**:xli–xlii, 2 fig.

Review of L. O. Howard's "The insect book." Country life in America **2**:lxiii–lxiv.

A yellow mud-dauber's nursery. Country life in America **3**:lxxxii, 1 fig.

A new economic entomology. Amer. nat. **36**·64–65.

Review of H. Kolbe's "Gartenfeinde und gartenfreunde. Die fur den gartenbau schadlichen und nutzlichen lebewesen." Garten-bibliothek 34–36.

The moth catcher humbug. Tree breeder **2**:3:3–4.

Some notes on early spring work against insects and fungi. Tree breeder **2**:4:1–3.

Tar for peach tree borer. Tree breeder **3**:1:2.

The scientific name of the cherry fruit-fly. Can. ent. **34**:28.

Report of section on Entomology. U. S. Dept. Agr., Office Exp. Sta. Bul. 115:21–22.

Some suggestions on notes. U. S. Dept. Agr., Office Exp. Sta. Bul. 115:120–123, fig. 1.

Sprays for green aphis. Rural New-Yorker **61**:52.

The powder-post beetle. Rural New-Yorker **61**:104.

Lyctus unipunctatus.

Potato beetles on tomatoes. Rural New-Yorker **61**:105.

Damage from "corn weevil." Rural New-Yorker **61**:124.

Angoumois grain moth, or a beetle(?).

Saving timber from powder-post beetle. Rural New-Yorker **61**:145.

Wash for apple trees. Rural New-Yorker **61**:170.

What ailed the cherry tree? Rural New-Yorker **61**:189.

Potash and caterpillars. Rural New-Yorker **61**:227.

Cure for powder-post beetles. Rural New-Yorker **61**:227.

Dipping peach roots for borers. Rural New-Yorker **61**:228.

1902 (*continued*)

Insects in rope, kinking. Rural New-Yorker **61**:228.
Spring wheat and the hessian fly. Rural New-Yorker **61**:228.
Lime, salt, and sulphur for the San José scale. Rural New-Yorker **61**:246.
Bitter rot in apples. Rural New-Yorker **61**:288.
Cedar rust of apples.
What the plum curculio does. Rural New-Yorker **61**.400.
Round-headed apple borer. Rural New-Yorker **61**·432.
Apple curculio attacking pears. Rural New-Yorker **61**.464.
What cure for fleas? Rural New-Yorker **61**:655.
How to kill apple borers. Rural New-Yorker **61**:688.
Fighting wireworms. Rural New-Yorker **61**:752.
The strawberry leaf-roller. Rural New-Yorker **61**:784.
Wire cages for apple borers. Rural New Yorker **61**:830.

1903

The ribbed cocoon-maker of the apple. By M. V. Slingerland and P. B. Fletcher. Cornell Univ. Agr. Exp. Sta. Bul. 214:67–78.
Destructive work of plant lice in New York orchards. Cornell Univ. Agr. Exp. Sta. Press notice, July 9, 1 page. Revised July 15.
The pear psylla again destructive in New York pear orchards. Cornell Univ. Agr. Exp. Sta. Press bul., July 15, 1 page.
Insects wanted. Cornell Univ. Agr. Exp. Sta. Press bul., August, 1 page.
Report of the Entomologist. Cornell Univ. Agr. Exp. Sta. Ann. rept. **16** for 1903:xvi–xvii.
Expert entomologist gives facts in case. Ithaca daily news, June 5, p. 5.
Cankerworm.
A big fight with grape pests. West. New York Hort. Soc. Proc. **48**: 75–78.
The elm leaf beetle found at Ithaca, New York. Ent. news **14**:30.
Compound vernacular names. Ent. news **14**:30–31.
A humming-bird moth. Country life in America **3**:cxxvii–cxxviii, 6 fig.
Facts about the seventeen-year locust. Country life in America **4**:136–137.
The insect destructive to fruits. In Thomas' "American fruit cultivator," 21st ed., p. 160–210.
The "tree preservation shield." Rural New-Yorker **62**:371.
The apple twig-borer. Rural New-Yorker **62**:372.
The cabbage maggot. Rural New-Yorker **62**:420.
Bollworm on tomatoes. Rural New-Yorker **62**:486.

1903 (*continued*)

Notes about some insects. Did ants injure the corn? Where potato beetles come from. Rural New-Yorker **62**:499.
Snails destroying tobacco plants. Rural New-Yorker **62**:516.
Life cycle of potato beetles. Rural New-Yorker **62**.532.
Strawberry leaf-roller. Rural New-Yorker **62**:532.
The story of the white grub. Rural New-Yorker **62**:564.
" Chiggers " or red mites. Rural New-Yorker **62**:612.
Work of the fall webworm. Rural New-Yorker **62**:644.
Arsenite of soda for spraying. Rural New-Yorker **62**:658.
Woolly aphis. Rural New-Yorker **62**:660.
Salt in the lime-sulphur wash. Rural New-Yorker **62**:707.
Slugs injure strawberries. Rural New-Yorker **62**:708.
Shot-hole borer in cherry tree. Rural New-Yorker **62**:709.
More about woolly aphis. Rural New-Yorker **62**:738.
The scale on fallen leaves. Rural New-Yorker **62**:771.
Sulphate of copper for scab. Rural New-Yorker **62**:819.
Potato scab.
Apple curculio. Rural New-Yorker **62**:820.
Use of arsenite of soda. Rural New-Yorker **62**:852.

1904

The grape leaf-hopper. Cornell Univ. Agr. Exp. Sta. Bul. 215:79–102.
The grape-berry moth. Cornell Univ. Agr. Exp. Sta. Bul. 223:41–60.
Two grape pests. I. Effective spraying for the grape root-worm. II. A new grape enemy: the grape blossom-bud gnat. By M. V. Slingerland and Fred Johnson. Cornell Univ. Agr. Exp. Sta. Bul. 224:61–73.
What our insect enemies cost. Cornell countryman **1**:106–107.
Entomology. Cornell Univ. Agr. Exp. Sta. Ann. rept. **17** for 1904:40–45.
The crusade against mosquitoes. Cornell nature study leaflets. New York Dept. Agr. Nature-study bul. 1:241.
Insect pests of house and garden. Cornell reading-course for farmers' wives. Series 2, no. 10:185–200d.
Report of the committee on entomology. New York State Fruit Growers' Assoc. Proc. **3**:24–29.
Removing insect pests. Farm stock journal, January 21.
Scale of fruit and forest trees. Amer. agr. **74**:4.
A small though " mitey " enemy. National nurseryman **12**:162.
Insect photography. U. S. Bur. Ent. Bul. 46:5–13, fig. 1–2.
Address, as president, at the sixteenth annual meeting of the Association of Economic Entomologists.

1904 (*continued*)

Some serious insect depredations in New Yo k in 1903. U. S. Bur. Ent. Bul. 46:69–73, pl II.

Troublesome insects of the year.

Same as above with alterations printed separately, 13 pages.

Notes and some new facts about some New York grape pests. U. S. Bur. Ent. Bul. 46:73–78, 1 fig.

Our insect enemies in 1903. West. New York Hort. Soc. Proc. **49**:72–77.

The grape leaf folder. Rural New-Yorker **63**:68.

Kerosene in bordeaux mixture. Rural New-Yorker **63**:132.

Hard to fight the bud moth. Rural New-Yorker **63**:209.

Walnut and cedar near apples. Rural New-Yorker **63**:214.

Yellow-necked caterpillar and cedar rust of apples.

Dipping small trees before planting. Rural New-Yorker **63**:234.

Insects working in pop corn. Rural New-Yorker **63**:262.

Angoumois grain moth(?).

Red spiders on walls. Rural New-Yorker **63**:284.

English sparrows and lice. Rural New-Yorker **63**:304.

The cabbage maggot and its handling. Rural New Yorker **63**:305.

The cauliflower root-maggot. Rural New-Yorker **63**:345.

Making a kerosene emulsion. Rural New-Yorker **63**:364.

" Downicide " for spraying trees. Rural New-Yorker **63**.380.

Fighting the cabbage maggot. Rural New-Yorker **63**:413.

How to kill canker-worms. Rural New-Yorker **63**:428.

Carbolic acid emulsion. Rural New-Yorker **63**:436.

Wireworms and beans. Rural New-Yorker **63**:444.

How to fight ants. Rural New-Yorker **63**:538.

Scarcity of potato beetles. Rural New-Yorker **63**:541.

Worms in field beans. Rural New-Yorker **63**:548.

White grubs in stable manure. Rural New-Yorker **63**:565.

Arsenate on apples. Rural New-Yorker **63**:574.

Fighting the buffalo carpet-beetle. Rural New-Yorker **63**:588.

White grubs in strawberries. Rural New-Yorker **63**:780.

Salt for quince borers. Rural New-Yorker **63**:796.

Sprays for southern vegetables. Rural New-Yorker **63**:811.

Fighting scale in young orchard. Rural New-Yorker **63**:825.

Injurious insects from Turkey. Rural New-Yorker **63**:925.

Yponomeuta sp.

1905

Two new shade-tree pests: sawfly leaf miners on European elms and alder. Cornell Univ. Agr. Exp. Sta. Bul. 233:47–62.

An interesting canker worm experiment. Cornell countryman **2**:157, 1 fig.

1905 *(continued)*

Some insect problems and experiences. West. New York Hort Soc. Proc. 50:95–100, 3 fig.

Rose chafer. National nurseryman 13:61.

Vineyard spraying — successful combats with insect enemies. Country calendar 1:269.

Codling moth; insects in sod orchards. Rural New-Yorker 64:57.
Woolly aphis.

Onion blight and onion maggot. Rural New-Yorker 64:226.

"New process lime" for bordeaux mixture. Rural New-Yorker 64:227.

Sal soda for hen lice. Rural New-Yorker 64:320.

Guarding against cabbage maggot. Rural New-Yorker 64:339, 2 fig.

Strength of the bordeaux mixture. Rural New-Yorker 64:370.

New-process limes in bordeaux mixtures. Rural New-Yorker 64:391, fig. 161–163.

Bands for the codling moth. Rural New-Yorker 64:407.

Angleworm queries. Rural New-Yorker 64:408.

Angleworms in cabbage. Rural New-Yorker 64:440.

Insects on strawberries. Rural New-Yorker 64:461.
Chrysomela suturalis.

Two troublesome insects. Climbing cutworms. The steely beetle on grape buds. Rural New-Yorker 64:471.

Getting rid of bats. Rural New-Yorker 64:477.

Poison for striped melon-bugs. Rural New-Yorker 64:505.

Remedy for apple borers. Rural New-Yorker 64:536.

An army of maggots. Rural New-Yorker 64:536.

Sod or clean culture for insects. Rural New-Yorker 64:549.

Cabbage maggots and fertilizers. Rural New-Yorker 64:552.

Bisulphide of carbon for ants. Rural New-Yorker 64:600.

Ups and downs of insects. Rural New-Yorker 64:727.

"This worm has feathers." Rural New-Yorker 64:742, fig. 316.

Soil containing white grubs. Rural New-Yorker 64:744.

1906

The bronze birch borer: an insect destroying the white birch. Cornell Univ. Agr. Exp. Sta. Bul. 234:63–78.

Cooperative spraying experiments. I. Experiments against the plum and quince curculios. II. Final demonstrations of efficiency of a poison spray for the grape root-worm. III. Making bordeaux mixture with "new process" or prepared lime. Cornell Univ. Agr. Exp. Sta. Bul. 235:79–98.

Entomology. Cornell Univ. Agr. Exp. Sta. Ann. rept. 18 for 1905:44–47.

1906 (*continued*)

Some San José scale notes. Cornell countryman **3**:158–160.
A campaign against San José scale. National nurseryman **14**:343–344.
Spraying for the San José scale. Metropolitan and rural home **16.** November. Figures.
Formaldehyde as an insecticide. Ent. news **17**:130–133.
A business experiment with scalecide against the San José scale. Syllabi of lectures at Normal Institute for farmers' institute workers. November 20 to December 1, 1906, p. 15.
An experiment with oil sprays. Rural New-Yorker **65**:17.
Late brood of codling moth. Rural New-Yorker **65**:173.
Sugar beets and wireworms. Rural New-Yorker **65**:280.
Plum curculio; bordeaux mixture. Rural New-Yorker **65**:346.
Lime and sulphur for hen lice. Rural New-Yorker **65**:455.
How to kill cabbage maggot. Rural New-Yorker **65**:520.
White grubs and potatoes. Rural New-Yorker **65**:846.
Millipede worms. Rural New-Yorker **65**:846.

1907

Some insect notes. Yates county chronicle [Penn Yan, New York], January 16.
Spraying. Metropolitan and rural home **17.** February.
Entomology as sometimes writ at Cornell. Cornell countryman **4**:153.
Entomology. Cornell Univ. Agr. Exp. Sta. Ann. rept. **19** for 1906:73–76.
My summer house. Country life in America **12**:xvi.
Some insect notes. New York State Fruit Growers' Assoc. Proc. **6**:99–104.
Some spraying philosophy and practice. West. New York Hort. Soc. Proc. **52**:29–32.
The more urgent problems in insect control. U. S. Dept. Agr., Office Exp. Sta. Bul. 196:104–109.
Powder-post beetles. Rural New-Yorker **66**:4.
Fighting the woolly aphis. Rural New-Yorker **66**:40.
San José scale on market fruit. Rural New-Yorker **66**:123.
Peach curculio. Rural New-Yorker **66**:256.
Insect on hop vine. Rural New-Yorker **66**:320.
The harlequin cabbage bug. Rural New-Yorker **66**:360.
Bedbugs in a henhouse. Rural New-Yorker **66**:583.
Corn ear worm; wireworms. Rural New-Yorker **66**:589.
White grubs and mealy bugs. Rural New-Yorker **66**:921.

1908

Insect pests and plant diseases: II. Insects and their control. III. Insecticides. By M. V. Slingerland and C. R. Crosby. Cornell Univ. Agr. Exp. Sta. Bul. 252:337–349. 2d ed. 1908.

Means of controlling insects. In Bailey's Cyclopedia of American Agriculture **2**:40–46, fig. 59–71.

Entomology. Cornell Univ. Agr. Exp. Sta. Ann. rept. **20** for 1907:47–48.

Report on insects. New York State Fruit Growers' Assoc. Proc **7**:18-20.

No danger from San José scale-infested fruit Canadian hort. **30.** December.

The importance of spraying. Metropolitan and rural home **18.** March, 2 fig.

The elm leaf beetle; a warning. Ithaca daily journal, April 28, p. 6.

The peach-tree borer. West. New York apple **1**:85–92.

Must the calyx cup be filled? Journ. econ. ent. **1**:252–254, pl. 7.

Habits of woolly aphis. Rural New-Yorker **67**:80.

Brown beetles on raspberries. Rural New-Yorker **67**:120.
Byturus unicolor.

" Roasting " out the scale. Rural New-Yorker **67**:125.

Plant lice on peas. Rural New-Yorker **67**:168.

The cabbage maggot. Rural New-Yorker **67**:259.

A talk about arsenic sprays. Rural New-Yorker **67**:287.

English sparrows and bedbugs. Rural New-Yorker **67**:338.

Elm leaf beetles. Rural New-Yorker **67**:452.

Work of the plum curculio. Rural New-Yorker **67**:473.

Fumigating for ants. Rural New-Yorker **67**:504.

Snails in cold frames. Rural New-Yorker **67**:521.

Formalin and angleworms. Rural New-Yorker **67**:522.

Habits of curculio and rose bugs. Rural New-Yo ker **67**:566.

Wireworms in corn. Rural New-Yorker **67**:617.

Habits of curculio and rose bugs. Rural New-Yorker **67**:633.

Fighting the strawberry weevil. Rural New-Yorker **67**:804.

Chemicals and the codling moth. Rural New-Yorker **67**:953.

1909

Angoumois grain moth. Rural New-Yorker **68**:6.

Infection with blight and woolly aphis. Rural New-Yorker **68**:84.

Facts about the gape worm. Rural New-Yorker **68**:177.

Must the calyx cup of the apple be filled? Better fruit **3**:29.

Some new fruit pests. New York State Fruit Growers' Assoc. Proc. **8**:121–126.

Some new fruit pests and other bug notions. West. New York Hort. Soc. Proc. **54**:89–95, 3 fig.

1910

The control of insect pests and plant diseases: I. Insects and their control. II. Insecticides. By M. V. Slingerland, G. W. Herrick, and C. R. Crosby. Cornell Univ. Agr. Exp. Sta. Bul. 283:466–479, fig. 191–205.

1914

Fruit insects. By M. V. Slingerland and C. R. Crosby.

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AGRICULTURAL EXPERIMENT STATION OF

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Department of Farm Management

SOME IMPORTANT FACTORS FOR SUCCESS IN GENERAL FARMING AND IN DAIRY FARMING

BY G. F. WARREN

The requirements of a good farmer are at least four:

"The ability to make a full and comfortable living from the land;
to rear a family carefully and well;
to be of good service to the community;
to leave the farm more productive than it was when he took it."

L. H. BAILEY

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CONTENTS

SOME IMPORTANT FACTORS FOR SUCCESS IN GENERAL FARMING AND IN DAIRY FARMING

G. F. Warren

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INTRODUCTION

For eight years the Department of Farm Management has been studying farms in order to learn why some farms pay better than others. Records have been obtained from six townships in Tompkins county, five townships in northern Livingston county, and five townships in Jefferson county. Records have also been obtained for a considerable number of farms in different parts of the State, in all 2743 farms. In addition to these records used for systematic study, probably over one thousand records have been made out for their home farms by students in this department. These have not been tabulated, but are in accord with the principles here given. Similar work has been done in fourteen other States. So far as the work in other States has been published and so far as the writer has heard it discussed in lectures, the same principles are shown to apply.

Distinction between a successful farm and a successful farmer. Profitable farms are usually not readily told by casual observation. A farmer who is not in debt may have a well-kept place and be living well, but not be making interest on his capital. His farm may make a good home, but it cannot be called a good business unless it pays interest on the capital invested and good wages for the farmer's labor. Another farmer who is in debt for his place and who has to pay interest, may be running a much more successful farm and yet have little money left over for good living. Not infrequently the owner of a very profitable farm fails to accumulate money. On the other hand, the owner of a farm that does not pay any labor income may save money.

The distinction between a successful farm and a successful farmer is well illustrated by a farmer in one of the counties studied. The farm is very successful, but the owner drinks and wastes all that he gets. The neighbors do not consider his farm to be successful because the owner is not accumulating any money, and they do not distinguish closely between a profitable farm and a thrifty individual. This man's farm is very successful. It is no fault of the system of farming that the money is wasted. The farm produces the money. In other cases, a farmer may spend his profits in educating his children and fail to accumulate money

as fast as a neighbor who makes less from his farm but who saves all he gets.

Financial success for an individual depends on spending less than one receives. A farm is a financial success when it pays a good rate of interest on the capital invested in addition to good wages to the operator

A way of measuring the success of a farm. Labor income defined. In order to compare different farms it is necessary to have a way of measuring profit. The most accurate way of comparing is on the basis of labor income, or farmer's wages. Labor income is the amount of money that the farmer has left after paying all business expenses of the farm and deducting five per cent for interest on the money invested in the farm business.

An illustration of the method of figuring may make the point clear. The averages for farms in Jefferson county are shown in Table 1. The

TABLE 1. AVERAGES. 670 FARMS, JEFFERSON COUNTY, NEW YORK

Average capital	$9,006
Average receipts	1,890
Average business expenses	735
Receipts less expenses	1,155
Interest at 5 per cent	450
Income from unpaid labor	705
Value of unpaid labor except owner's	96
Labor income	609

average capital on these farms was $9006. This includes land, buildings, stock, machinery, tools, feed and seed on April 1, and cash to run the farm. The average receipts for the year were $1890. Any unsold products or increase in animals is counted as a receipt. The average expenses were $735. This includes all business or farm expenses. It does not include any personal expenses, but includes the value of board furnished to hired help.

The difference between receipts and expenses averaged $1155.

This $1155 was earned by the farmer's money and the work of the family. Money can readily be loaned on farm mortgages at five per cent. Hence, only $705 can be said to have been earned by the labor of the farmer and his family. The unpaid farm labor by members of the family would have cost about $96 if it had been hired, therefore the average farmer really earned $609 as wages for his own work. This we call his labor income. Hired men in this region get about $400, house rent, and some farm products. If a farmer's labor income is less than this, he may as well lend his money and hire out.

The term " labor income " is readily understood by farmers, because it is directly comparable with hired man's wages when the hired man gets a house, a garden, and some farm products. It is not so readily understood by persons in the city. Such persons usually assume that the purpose of this work is to show that farmers either are, or are not, getting rich too fast. The purpose of this work is to determine why some farms pay better than others. The aim is to compare farms with farms, not to compare farms with the city. If one wished to make such a comparison he should have no more difficulty in comparing labor income with city wages than he has in comparing farm wages for married men with city wages. In either case, the person on the farm receives house rent and some farm products in addition to the labor income, or wages. The object of calculating labor income is to have a basis for comparing different farms. It serves this purpose most excellently.[1]

The man as a factor in success. It is frequently stated that success depends on the man. To some persons this seems a full and satisfactory explanation. But it explains nothing. It merely dodges the question. Success cannot come from *merely being* a genius. Success comes from *doing* certain things. The farmer does not sell himself. He sells milk, potatoes, hay, apples. It is such things as cost of production, amount sold, and price that determine his profits. The only way that a good farmer can express himself is by *doing* certain things. These things are fairly easy of analysis. If one farmer sprays his apples and another does not, it is the arsenic that kills the worms. Any other person can duplicate the result by spraying in the same way. If one farmer succeeds because he has better cows than another, this success can be duplicated. Certainly some persons will succeed where others fail, because they do things differently. Just what are the differences in method of procedure?

Many of the limiting factors are natural forces over which the farmer has little, if any, control. Other limiting factors that are not personality are prices, roads, freight rates, capital, and the like. These limit what can be done by the best, as well as by the poorest, farmer. With large numbers of records, it is possible to determine with a fair degree of accuracy the influence that each of the different factors has on profits. Any part of a farmer's success that is due to his acts can as readily be determined

[1] Business men sometimes question why the value of the farmer's labor is not deducted and interest calculated, rather than deducting interest and calculating labor. In our first two years of work, we made calculations both ways. But with such small investments as some farmers have, the interest figure often means nothing. If a farmer has a capital of $2000 and makes $600 above his farm expenses, his labor income is $500. If we assume that his labor is worth $400 at farm wages, then he has made 10 per cent interest. Another farmer with $20,000 capital whose farm receipts exceed the expenses by $2000, makes a labor income of $1000. If the labor that he does is considered to be worth $400, he makes 8 per cent interest. If all farmers had capitals of $20,000 to $50,000, so that interest would be a larger item than labor, the interest method of figuring might be considered. Another reason why labor income is preferable is that we know what money is worth. It is much more difficult to assign a value to the farmer's labor.

when large numbers of farms are studied. (See Fig. 102 and discussion of it.) The confusion is increased by failure to distinguish between a successful farm and a successful individual, as has already been pointed out.

What are the differences in natural conditions, and what are the ways in which the organization and management of successful farms differ from the natural advantages and management of less successful ones?

Factors affecting profits. There are hundreds of things that have some effect on profits, but many of these can make only a slight difference. There are many other factors that set absolute limits to the profits. Of these important factors, a few stand out as the prominent ones on the vast majority of farms. From a long study of this question, it is found that the factors that most frequently determine whether the profits are poor, good or excellent are the size of the business, the diversity of the business, the crop yields, and the production per animal. For general farms, the labor income can be placed in the correct group in about eighty per cent of the cases, if one knows the area of crops grown, the yields of these crops, the receipts per cow or other important animal, and the percentage of the total receipts that come from cash crops. In other words, these four are the most important factors that control profits in farming.

Of two farms that have practically the same area of crops, same yields, same receipts per cow, and same proportion of receipts from animals, one may have a labor income of $600 and the other $800. Many other minor factors produce these small variations. Rarely do we find farms that are alike in the four factors mentioned above and that have such differences as $600 and $2000 in labor income. There are, of course, many factors that might cause such a difference, but in actual experience the fact is that they do not often do it. None of these conclusions were derived by theory. They were found by sorting records of farms in many ways and examining the results. The writer would have arrived at entirely different conclusions from theory. It must also be remembered that the records include all farms in the regions studied, with the exceptions noted on page 664. They are not selected in any way.

SIZE OF BUSINESS

Ways of measuring size. There are many ways of measuring size of business. Farms may be compared as to the amount of capital invested, number of men kept, number of cows or other animals, number of work animals, acres of land, or acres of crops grown. So long as we are dealing with fairly uniform conditions, each of these comparisons gives about

the same average results. If comparisons are made between widely different types of farming, as between truck growing and general farming, then capital is the best measure of size.

Relation of capital to profits. Very few farmers who use less than $5000 worth of capital are making good labor incomes. With a fair amount of capital, it is easier to make wages and interest on the larger capital than to make wages and the smaller interest on a small capital. The capital need not all be owned. Part or all of the land may be rented, or the land may be owned but mortgaged. Results in Bulletin 295 of this station agree with this, as they do with all the results in this bulletin. The relation of capital to profits is shown by Tables 2, 3, and 4:

TABLE 2. CAPITAL RELATED TO LABOR INCOME. 578 FARMS, NORTHERN LIVINGSTON COUNTY, NEW YORK

Capital	Number of farms	Average labor income
$ 5,000 or less	87	$ 291
5,001– 7,500	80	407
7,501–10,000	112	480
10,001–15,000	164	769
15,001–20,000	62	1,001
20,001–30,000	55	1,062
Over 30,000	18	1,691

TABLE 3. RELATION OF CAPITAL TO PROFITS. 578 FARMS, NORTHERN LIVINGSTON COUNTY, NEW YORK

Capital	Per cent of farmers making labor incomes of over $1,000
$ 5,000 or less	7
5,001– 7,500	11
7,501–10,000	16
10,001–15,000	33
15,001–20,000	46
20,001–30,000	51
Over 30,000	50

TABLE 4. RELATIVE OPPORTUNITIES WITH A GIVEN CAPITAL, AS OWNER, PART OWNER, AND TENANT, NORTHERN LIVINGSTON COUNTY, NEW YORK

Capital of operator	Owners operating their own land only		Owners renting additional land		Tenants	
	Number of farms	Average labor income	Number of farms	Average labor income	Number of farms	Average labor income
$ 1,000 or less	0	.....	0	.	20	$ 368
1,001– 2,000	3	$ 38	0	..	65	481
2,001– 3,000	10	81	8	$ 145	54	610
3,001– 4,000	16	195	9	462	27	626
4,001– 5,000	23	347	7	570	16	869
5,001– 7,500	46	355	14	485	More than $5,000: 22	1,282
7,501–10,000	62	400	19	583		
10,001–15,000	75	694	19	705		
15,001–20,000	28	935	3	1,018		
Over 20,000	29	1,412	3	2,269		

The reason why tenants and part owners make more than owners, as shown in Table 4, is because with a given capital they have a larger business. A tenant who has $3000 may rent a farm worth $15,000 and be running a business many times larger than can an owner who has only $3000. Any factor that enables the farm operator to get control of more capital results in much larger profits on the average.

The farmers with a given capital who have borrowed money so as to enlarge their business are, on the average, doing better than those who are not in debt. The results for one capital group in Jefferson county are given in Table 5. The farmers who were able to have larger farms because they borrowed money were making much better labor incomes than were those who farmed only as much land as they could pay for.

TABLE 5. EFFECT ON PROFITS OF ENLARGING THE FARM WITH BORROWED CAPITAL. FARMS WITH AN OWNED CAPITAL OF $5000 TO $10,000, JEFFERSON COUNTY, NEW YORK

	Farms mortgaged	Farms not mortgaged
Number of farms	82	64
Average capital owned	$7,074	$6,952
Average capital borrowed	0	$2,281
Average size of farm (acres)	113	141
Average labor income	$414	$665

The same point is shown for each county in each capital group up to $15,000. With a given owned capital of less than $5000, those who use their money to farm as tenants are making the most. The next most profitable way to use this amount of money is to buy a farm larger than the money will pay for, leave the balance on mortgage, and then rent additional land. The least profitable way of using this sum of money is to buy and equip a farm so small that one is not in debt, and then not rent any land.

Those persons who owned over $15,000 worth of property and who were not in debt made a little more than those who went in debt for additional property. This amount of capital gave them farms of 237 acres in Jefferson county and of 230 acres in Livingston county. This agrees with the discussion on size of farm in the following pages, where it is shown that if one has a small farm additional acreage is of very great importance, but that after 200 acres is passed more land may be desirable but is not so necessary.

One important point not shown in Table 4 is the profit due to rise in land values. If land is likely to rise in price, it may pay a tenant to invest his money in land even though his labor income is much lower than it might be as a tenant. Rising land values are not included in labor income. Ways of farming with small capital are discussed in Bulletin 295 of this station.

Similar results for three other States are given in Bulletin 41 of the United States Department of Agriculture, pages 19 to 22. In these States — Iowa, Illinois, and Indiana — more capital is required because the land is higher in price, but the same principles are shown to hold.

Relation of size of farm to profits. Tables 6 and 7 and Figs. 102 and 103 show the relation of size of farm to profits. These tables include all the

TABLE 6. RELATION OF SIZE OF FARM TO LABOR INCOME. 1988 FARMS, TOMPKINS, LIVINGSTON, AND JEFFERSON COUNTIES, NEW YORK

Acres	Number of farms	Average number of acres per farm	Average labor income
30 or less	74	22	$121
31– 50	141	44	252
51–100	616	79	402
101–150	572	126	568
151–200	304	177	776
Over 200	281	281	995

TABLE 7. VARIATIONS IN LABOR INCOMES WITH DIFFERENT SIZES OF FARMS. 1988 FARMS, TOMPKINS, LIVINGSTON, AND JEFFERSON COUNTIES, NEW YORK

Acres	Per cent of farms of each size making labor incomes as designated					
	Less than $1	$1 to $500	$501 to $1000	$1001 to $1500	$1501 to $2500	Over $2500
30 or less	27	70	3	0	0	0
31– 50	18	62	17	3	0	0
51–100	11	55	28	5	1	0
101–150	13	38	30	13	5	1
151–200	9	31	27	22	9	2
Over 200	12	20	24	20	18	6

farms in Tompkins, Livingston, and Jefferson counties for which records were obtained, except twenty-six highly specialized truck farms, one farm of a poultry fancier, one certified milk farm, and two farms devoted wholly to grazing. A number of farms were also omitted because the owner derived a very large part of his income from buying and selling live-stock, keeping boarders, or some other outside labor. Farms that sold a large amount of lumber were also omitted because this is not an annual crop. Some farms were omitted because they were on the edge of towns where the land values were excessive. Such farms are more in the real estate business than in farming. The truck farms will be considered later.

Most of the farms here included are rather general farms. On the majority of these, dairy cows are the chief live-stock interest, but many of them kept only a few cows. Some kept sheep. All kept some hens, and a few kept several hundred. The crop sales are varied. The most common crops sold were hay, potatoes, apples, cabbage, beans, wheat. Many other crops were sold from some farms. Nearly all the farms raise hay and oats to feed. Some raised corn for grain. Those that kept many cows usually had silos. The types of farming are representative of perhaps 90 per cent of the New York farms. Some of the farmers sold truck, but highly specialized truck farms are not included, nor are farms that derived much income from greenhouses included. When comparing farms on the acre basis, it would, of course, be misleading to include truck farms and greenhouses with general farms and dairy farms.

The average farmer with 30 acres or less of land made $121 for his year's wages. The average farmer with over 200 acres made over eight times

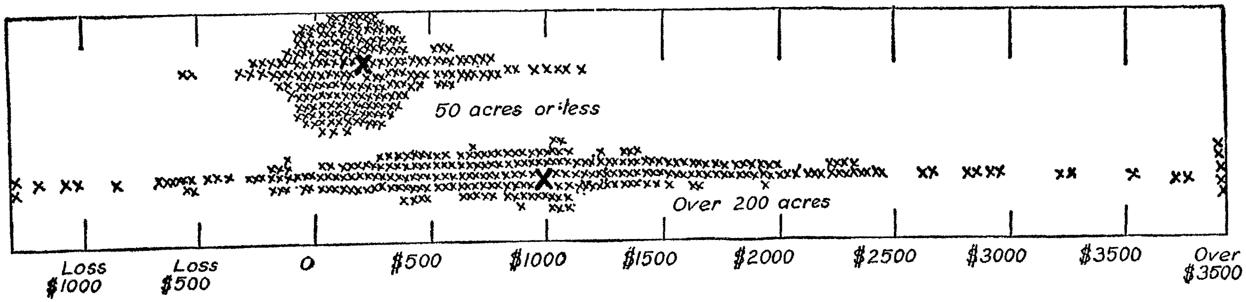

FIG. 102.— Labor incomes on 215 individual farms of 50 acres or less and on 281 farms of over 200 acres. The large X indicates the average for each group as given in Table 6. Each small cross indicates one farm and its position indicates the labor income.

The chances for profit or loss on the small farms are very closely limited, as is shown by the close grouping in the figure. Nearly all the farms of less than 50 acres made labor incomes from a loss of $200 to a gain of $400. It is very difficult to make a large profit and there is very little danger of a large loss on a small place.

The farms of over 200 acres bring opportunities for both success and failure. The great majority of the farmers on these farms make more than the average on the small farms. But a few lost much more than it is possible to lose on a small place. Eight farmers made $3500 to $7250. There is not room on the diagram to show these in their proper places.

Of the large farms 53 made lower labor incomes than the average small farm, but 101 did better than the best small farm. Only 4 of the small farms did as well as the average large farm.

The extremes only are given on the diagram. The farms of 51 to 100 acres are grouped rather closely, much like those of 50 acres or less. The farms of 100 to 200 acres show a gradual spreading out and a constantly increasing number of those making good profits as the opportunities increase.

as much. Of the seventy-four who farmed 30 acres or less, only two made over \$500. One of these made a labor income of \$534. He sold considerable truck, and probably should not have been included with general farms. The other made a labor income of \$511. He hired out as a farm hand for nine months, and raised potatoes, eggs and some milk to sell.

Of the farms of 50 acres or less, only four made labor incomes as high as \$1000. One had a 40-acre farm, combined bees with general farming, and made most of his money on honey. His labor income was \$1001.

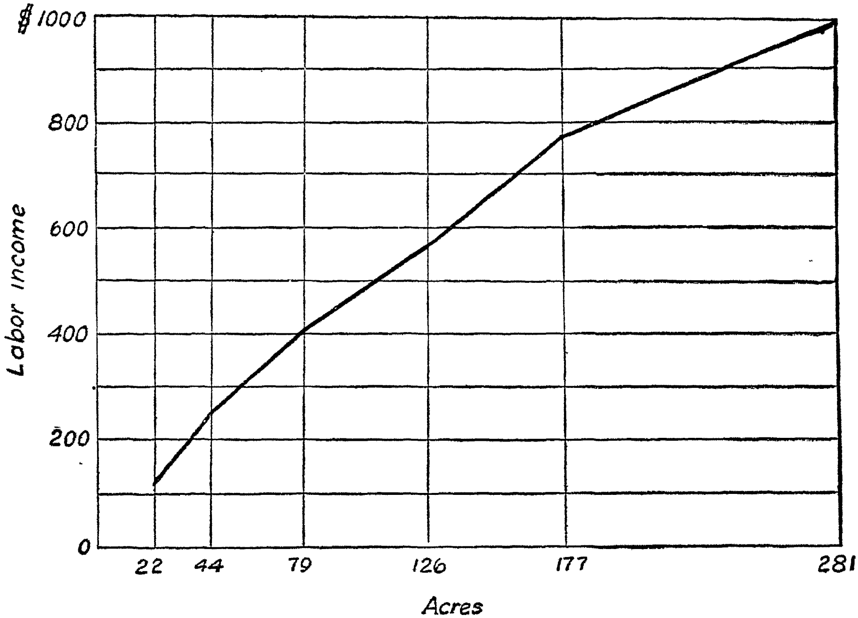

FIG. 103.—*Relation of size of farm to labor income on 1988 farms. With a small area additional acres increase the labor income very rapidly, but with over 177 acres additional land is not so important. Another 100 acres added to a farm of 79 acres increases the labor income by nearly \$400, but a second 100 acres further increases it by only a little over \$200*

Another had a 40-acre general farm that he ran in addition to hauling milk every day in the year. His labor income was \$1042. Most of his money came from hauling milk. Another made a labor income of \$1051 from a 40-acre farm by retailing milk. The fourth made \$1159 from a 50-acre general farm. He had a good crop of cabbage, which sold for \$22 per ton. It will be seen that each of these had unusual conditions.

Of the farms of less than 30 acres, only two made over \$500, but 68 per cent of the farms of over 200 acres made more than this amount and 24 per cent made over \$1000. The average for the farms of over 200 acres was \$995.

Figure 103 is a diagram of the results given in Table 6. This shows how rapidly the labor income increases with the size of farm. The shape of the curve also shows that additional area is of great importance up to 177 acres, but that after this it is of less importance. Adding 100 acres to a 177-acre farm increases the labor income about half as much as it does when added to a 79-acre farm.

These results are in no way local in their application. Similar studies in New Hampshire have shown the same results. A study of 277 farms in Iowa, Illinois, and Indiana showed the same relationship between size of farm and profits. The farmers with less than 160 acres of land made very poor labor incomes.[2]

Tenants on the larger farms are also making very much more than those on the smaller farms. The percentage received by the landlord is about the same with different sizes of farms (Bulletin 295 of this station, page 417). The reason is that the tenant furnishes machinery, horses and labor, and these are the chief items on which a saving is made by having a large farm.

Relation of size of farm to efficiency in the use of labor. In every county studied, the small farms accomplish much less per man than do the fair-sized farms. Table 8 gives results for Jefferson county. The average number of men per farm as given in the table includes all human labor. Work of women and children is expressed in terms of the number of men that would have been required to do the same work. On the smallest farms, very little work was done by any one except the operator. On the farms of over 200 acres, the hired labor and labor by members of the family amounted to the time of one and one third men, or, counting the time of the farmer, these farms had the equivalent of 2.35 men.

In making comparisons of farms, it is necessary to have some basis for comparing the different kinds of animals. One horse, cow, or bull is called an animal unit. Two head of young stock are counted as one animal unit. Seven sheep, 14 lambs, 5 hogs, 10 pigs, 100 chickens, are each counted as an animal unit.[3]

The farms of less than 30 acres had an average of 3.5 animal units per farm besides work horses. Those of over 200 acres had an average of 34.2 animal units besides work horses.

The producing enterprises on the farm are the acres of crops grown and the animals other than horses. The horses do not often contribute to the income. Even if colts are raised, they usually decrease the cost of horse labor rather than actually add to the income.

[2] U. S. Dept. Agr., Bureau of Plant Industry. Circular 75, pages 11–16.
U. S. Dept. Agr. Bulletin 41, pages 24–29.

[3] Cornell University Agricultural Experiment Station. Bulletin 295, page 473.

The acres of crops grown, the yields of these crops, the number of producing animals and the production of these animals are a measure of the amount that is being accomplished on a farm. The crop yields and the production of animals are no better on the small farms than on the large farms, hence the acres of crops and animals kept are a fairly accurate measure of the amount accomplished. The acres of crops raised per man varied from 13 on the small farms to 57 on the largest farms. The number of animal units per man varied from 3 on the small farms to 15 on the largest farms (Table 8).

TABLE 8. RELATION OF SIZE OF FARM TO EFFICIENCY IN THE USE OF LABOR. 670 FARMS, JEFFERSON COUNTY, NEW YORK

Acres	Average man equivalent	Average acres of crops	Average number of animal units except work horses	Acres of crops per man	Animal units except horses per man
30 or less	1.04	14	3 5	13	3
31- 50	1.18	25	7 9	21	7
51-100	1.34	40	13.2	30	10
101-150	1 61	66	19.4	41	12
151-200	1.98	89	25 1	45	13
Over 200	2 35	134	34 2	57	15

Relation of size of farm to work done. From cost accounts and other records, we know approximately how much time it takes to do each kind of farm work under normal conditions. The raising of an oat crop ordinarily takes 15 to 25 hours of man labor and 20 to 40 hours of horse labor per acre. With anything like efficient methods of work, 20 hours of man labor and 30 hours of horse labor per acre is sufficient. Many New York farmers do better than this. We may therefore say that an oat crop represents two days of man work and three days of horse work. As in doing any kind of work, some persons do it in less and some in more time. If much more time than this is spent, the work is not efficiently done. This may be because the fields are too small, because of poor machinery, because the land is unusually hard to work, or for other reasons. It matters not why time is lost. If it is lost the farm is not efficient.

Similarly the average farmer spends about 150 hours of work per year on a cow. If the barn or pasture is unhandy, or if he has only a half-

dozen cows, more time may be required. Some farmers who get good returns spend less time. To care for a cow for a year may be counted as about 15 days work.

In order to compare farms, all the productive enterprises are similarly expressed in work units. The income of the farm is dependent on the crops raised, the cows and other productive animals kept, the outside work done for pay. Much other work may be done, such as repairing machinery and buildings, taking care of work horses, mowing the lawn, etc., but it is the productive work that limits the income. The units of productive work of all kinds were calculated for each farm in Jefferson county. The units used for the more common enterprises were as follows:

	Man work units	Horse work units
Timothy, alfalfa, clover, per acre per cutting	1	1
Oats, wheat, barley, rye, buckwheat, per acre	2	3
Corn, husked from shock, per acre	6	6
Corn for silo, per acre	6	7
Field beans, per acre	5	5
Potatoes, per acre	12	10
Cabbage, per acre	13	12
Apples, per acre	15	5
Dairy cow	15	2
10 cattle or colts running loose	20	1
10 brood sows, and raising pigs to weaning	30	5
50 hogs, not brood sows	25	5
100 ewes	50	3
100 hens	15	2
Raising 200 chickens	15	2

TABLE 9. RELATION OF SIZE OF FARM TO EFFICIENCY IN THE USE OF MEN AND HORSES. 670 FARMS, JEFFERSON COUNTY, NEW YORK

Acres	Units of productive work per man	Units of productive work per horse
30 or less	102	35
31– 50	154	41
51–100	205	57
101–150	245	62
151–200	253	65
Over 200	294	76

The average amount of productive work per man varied from 102 work units on the small farms to 294 on the largest farms. Each man on the largest farms is accomplishing nearly three times as much work as the men on the small farms. It must be remembered also that the crop yields and the returns per cow are as good on the larger farms. Each horse on the large farms is accomplishing twice as much as each horse on the small farms. The farms of less than 100 acres are very wasteful of both man and horse labor.

Relation of size of farm to efficiency in the use of horses. The discussion given above is the best way of comparing horse labor. Another comparison is shown in Table 10. On the large farms, twice as many acres of crops are raised per horse as on the small farms. The average cost of keeping a horse on New York farms, as shown by cost accounts, is about $150 a year. This includes feed, labor, depreciation and all other costs. From this the importance of the efficient use of horses is apparent.

TABLE 10. RELATION OF SIZE OF FARM TO EFFICIENCY IN THE USE OF HORSES. 1248 FARMS, JEFFERSON AND LIVINGSTON COUNTIES, NEW YORK

Acres	Number of farms	Acres of crops	Number of horses	Acres of crops per horse
30 or less	42	14.2	1.5	9.5
31– 50	64	28.4	2.3	12.3
51–100	315	46.8	3.1	15.1
101–150	364	73.5	4.2	17.5
151–200	226	98.7	5.0	19.7
Over 200	237	152.8	7.2	21.2

Relation of size of farm to efficiency in the use of machinery. The small farms are very inadequately equipped with machinery, as is shown in Table 11. Even the farms of over 200 acres have an investment in

TABLE 11. RELATION OF SIZE OF FARM TO EFFICIENCY IN THE USE OF MACHINERY. 1248 FARMS, LIVINGSTON AND JEFFERSON COUNTIES, NEW YORK

Acres	Acres of crops	Value of machinery	Value of machinery per acre of crops
30 or less	14.2	$141	$9.93
31– 50	28.4	207	7.29
51–100	46.8	426	9.10
101–150	73.5	497	6.76
151–200	98.7	613	6.21
Over 200	152.8	833	5.45

machinery of only $833. This represents machinery of all ages. Probably the cost when new would be over twice as much, but even this sum will not provide all the well-established machines, such as a grain-binder, manure-spreader, and hay-loader for each farm. But, while the small farms are not well equipped, their cost of machinery per acre of crops is almost double that on the larger farms.

Relation of size of farm to efficiency in the use of capital. The small farm has relatively much more of its capital invested in unproductive ways than does the large farm. No matter how small the farm may be, the owner desires a respectable house. Table 12 shows that the smallest

TABLE 12. AREA RELATED TO INVESTMENT IN BUILDINGS. 578 FARMS, LIVINGSTON COUNTY, NEW YORK

Acres	Value of houses	Per cent of total capital in houses	Value of other buildings	Per cent of total capital in other buildings	Value of other buildings per animal unit
30 or less	$1,494	43	$ 655	19	$164
31– 50	1,000	23	681	15	95
51–100	1,236	18	1,091	16	87
101–150	1,477	14	1,408	13	74
151–200	1,810	13	1,900	13	73
Over 200	2,113	9	2,552	11	50

farms have 43 per cent of their capital in houses; the largest farms have somewhat better houses, but have only 9 per cent of their capital thus invested.

The barns on the small farms also take a much larger proportion of the capital. The smallest farms have 19 per cent of their capital thus invested, the largest farms have only 11 per cent thus tied up. An equally good barn for ten head of stock costs much more than half as much as a barn for twenty head of stock. The smallest farms have an investment in barns of $164 per animal unit.[4] The largest farms have only $50 per animal unit. Yet observations lead to the conclusion that the stock on the larger places is better housed. If interest, repairs, depreciation, and insurance on a building amount to 10 per cent of the value, then the housing cost per animal unit will vary from $16 per year on the smallest farms to $5 per year on the largest.

[4] For definition of "animal unit" see page 667.

Similar results for the United States are shown in Table 13. These indicate, as for other points in this work, that the results are of general

TABLE 13. AREA RELATED TO INVESTMENT IN BUILDINGS AND MACHINERY, FOR UNITED STATES, 1909, FROM THE CENSUS REPORT

Acres	Value of buildings per farm	Per cent of capital in buildings	Value of machinery	Per cent of capital in machinery
Under 20.	$ 605	34	$ 56	2.5
20– 49.	474	21	76	2.8
50– 99.	848	19	156	3.1
100–174.	1,182	14	241	2.7
175–499.	1,734	10	390	2.4
500–999	2,174	8	639	2 4
1,000 or over.	3,330	5	1,196	1.0

rather than local application. The farms of less than 20 acres have 36 per cent of their capital invested in buildings and machinery. Those of 100 to 174 acres have only 17 per cent of the money thus invested, yet they have much better buildings and more machinery. Money thus employed not only is unproductive, but is a source of constant cost for repairs. If a farmer had all his money invested in buildings and machinery, his income would, of course, be zero. In fact, he would not be a farmer at all.

Relation of size of farm to crop yields. The larger farms produce crops as good as, or better than, those produced on the small farms, as is shown in Table 14. Since the small farms keep more horses and men, the amount

TABLE 14. SIZE OF FARM RELATED TO CROP YIELDS, LIVINGSTON COUNTY, NEW YORK

Acres	Average size (acres)	Acres per animal unit	Yield per acre of				
			Wheat (bushels)	Oats (bushels)	Hay (tons)	Potatoes (bushels)	Beans (bushels)
30 or less...	20	5.0	18	39	1.21	92	18
31– 50....	44	6.3	19	40	1.58	98	18
51–100....	79	6 1	19	41	1.49	116	18
101–150.....	125	6.6	19	42	1.53	108	16
151–200.....	173	5.8	19	47	1.39	111	17
Over 200.....	300	5.9	19	43	1.45	116	15

of product that they have left over is less per acre than the amount left for city consumption from the larger farms. In addition, there is a waste of human labor and resources in making machinery and buildings that are not given full use on the small places. From every standpoint, the farms that are large enough to keep machinery and horses busy and provide full work for a farmer and his sons are most desirable.

The relation of the number of acres of crops to the yield of crops is shown also in Table 15. The farms with less than 20 acres of crops have

TABLE 15. RELATION OF ACRES OF CROPS TO LABOR INCOME. 578 FARMS, LIVINGSTON COUNTY, NEW YORK

Acres of crops	Average acres of crops	Number of farms	Labor income	Crop yields compared with the average of the region (per cent)
20 or less	14	18	$ 24	75
21– 40	31	55	257	102
41– 60	51	95	400	103
61– 80	69	115	481	102
81–100	90	95	642	101
101–140	118	112	937	103
Over 140	193	88	1,261	100

poor crops, probably because they cannot afford the necessary machinery. Aside from this there seems to be no relationship between the acres of crops grown and the yields per acre.

Results in other States. Bulletin 41 of the United States Department of Agriculture, pages 24 to 29, shows that the same principles governing the size of farm apply in Iowa, Illinois and Indiana. Few farms of less than 160 acres were giving good labor incomes. The labor cost per acre of crops was high on small farms. The acres of crops raised per horse was low and the cost of machinery was very high on the small farms. The crop yields were as good on the large farms as on the small ones.

Relation of area in crops to profits. Probably a more accurate way of measuring the size of farms is to compare the area in harvested crops. This is in addition to pasture, woods and other land not cropped. Results of such a comparison are shown in Table 15. The results for the other counties agree with those here published.

Most of the economies in production are dependent on the area of crops grown. Five horses can raise 100 to 125 acres of general farm crops when

the crops consist of a good combination of grain and hay combined with potatoes, apples or cabbage. If the crops are of the above kinds, there should be at least 20 acres per horse, but if they are largely hay and grain there should be at least 30 acres per horse. In the Eastern States, the cost of horse labor per acre is more than the interest on the land. While five horses can raise 125 acres of crops, it is difficult to raise 50 acres of crops with two horses. Farm machinery is built on the two-, three-, and four-horse basis. Evidently, if one has less than 80 acres of crops, he must go without good machinery or must keep too many horses. There is no solution of the problem for him. Machinery, horses and labor cannot be used to the best advantage with less than 100 to 125 acres of crops, 150 to 200 acres is still better.

Truck farms. The preceding discussions should not be confused with truck farms. In Livingston county, records were obtained for 17 truck farms on muck soil. The chief crops on this soil were lettuce, celery, spinach and onions. This type of farming is highly speculative. Crops are by no means sure and prices are extremely variable. One of these farmers made a labor income of $2931 from 8 acres. This is the highest labor income thus found for so small a farm. Another of these muck farms lacked $1934 of having any labor income.

In Jefferson county, records were obtained for 10 truck farms. Most of these used lowland soils that were not true muck. Seven had 20 to 50 acres. Their average labor income was $662. Three had over 50 acres and made an average labor income of $789.

Unusual conditions may affect results. Exceptional prices or exceptional land values may decidedly affect results. The results for a 15-acre dairy farm that was formerly operated by Mr. Dietrich [5] have been widely quoted and have been the cause of much misunderstanding. The farm was fairly profitable. Apparently a labor income of about $1000 was made. The farms studied in New York of over 200 acres probably had an average capital of no more than this man had invested, but 44 per cent of them made labor incomes of over $1000.

Mr. Dietrich sold milk to a state institution at 6¼ cents a quart wholesale, the year round. At ordinary wholesale prices he would have lost money. He did very well for his conditions, but his conditions were entirely unusual. Land was worth city prices, so that he could not afford much of it. Milk was at an exceptional price.

In cities there are successful dairies with less than an acre of land. They buy their cows and buy all the feed and bedding. But such dairymen get more for their milk because of their location. It would

[5] U. S. Dept. Agr. Farmers' bulletin 242.

be impossible for them to produce milk at a profit if it were sold at wholesale farm prices. Such special cases do not in any way affect the general principles as to the importance of size of farm.

Profits on very large farms. At the same time that small farms in the general farming States are being combined, the very large farms have been decreasing in number. All the discussions given above apply to "family farms" on which the farmer and his family do most of the work. On the farms of over 200 acres in Livingston county, there was an average of less than two hired men per farm. In Jefferson county, the farms of over 200 acres had an average of one hired man per farm. In each county the farms of less than 150 acres furnished work for less than one person besides the farmer.

There are many reasons why very large farms are at a disadvantage. Even with the buildings in the center of the farm, it is not often profitable to run more than 600 acres from one center, because of the loss of time in going to and from the fields. The great variety of work that must be done makes it difficult to handle men in gangs and use them like machines. The large area over which operations must be conducted makes it impossible to use factory methods. The frequent changes of work on a moment's notice, because of weather or other conditions, makes it difficult to prevent loss of time in shifting from one job to another. The prices of farm products are based on production by the farm family with a little hired help. This sort of labor is interested and accomplishes much more than can be done by a large farm where the men have no direct interest. It is very difficult for the "bonanza" farm to compete with these conditions.

Ways of increasing the size of business. Some persons have drawn the erroneous conclusion that a man with a small capital cannot be a farmer because a large farm is necessary. This is far from the case. One with no money can be a hired man. One who has $1000 to $2000, who knows how to farm, and who is efficient and honest can rent a good farm. There are many ways of getting control of a good-sized farm without owning it all. Only 36 per cent of the farmers in the United States own all the land that they operate and are free from debt.

Some farmers who have small farms and who are not in debt would do well to borrow money and buy more land. Many farmers have taken this means of increasing the size of their business.

There are over half a million farmers in the United States who own part of the land that they farm and rent additional land. This is usually farmed with little more men, horses or machinery than would have been required to farm the land owned. Very frequently this is the best solution of the problem for one who already owns a farm. In every county and

in every State where such studies have been made, the farmers who rent additional land make more than those who farm only as much as they own.[6]

Another way of increasing the size of the business is to use the land for a more intensive type of farming, as poultry-raising or truck growing. The soil, climate, transportation and other factors have such a controlling influence on type of farming that one should give the matter careful study before attempting a type of farming that is not already followed in the region. Farmers have tried almost everything. The present types of farming are the ones that have stood the test. They are usually not far wrong.

On many farms, the acres of crops can be increased by changing brush land to pasture and farming the pasture land. Other farms have land that can be reclaimed by drainage. There are other cases in which land is already being used too intensively. There is no use in planting crops if the yield is so poor or the labor so great as to make a profit impossible.

Many farmers on small places hire out for various kinds of work and thereby increase their incomes.

In many instances, it is better to remain a tenant on a large farm rather than buy a place that is too small for efficient farming. This problem is a hard one to answer, because of the uncertainty as to the rise in land values. If prices are likely to rise much in the region, it will pay to change from tenant to owner sooner than would otherwise be desirable.

For general farming, one should ordinarily hesitate to work a farm unless he can raise 80 acres of crops on it or can rent additional land.

Conclusions as to the best size of farm. Many farmers get their start on smaller places and by economy are able to save money, but for general farming or dairy farming there are great advantages in having at least 150 acres of land. On the average farm studied this would include about 80 acres of crops. An area that provides for 100 to 200 acres of crops is very much better.

There are many farm operations that require two men. On a one-man farm, the horses are kept out of the field, whenever the farmer does chores, hand work, or goes to town. On a two-man farm, one man may be using all the horses while the other man does other work. If there are four or five horses on the place, the man who is working the teams may be driving three or four horses, and at the same time the other man may make a trip to town with one horse. All the horses are then kept at work. A farm with five horses has a great advantage in being able to adjust the size of team to machinery and work. It allows a five-horse team; a four-horse team, or two two-horse teams with a single horse for other work; or allows a three- and a two-horse team. By these means, the labor of

[6] Cornell University Agricultural Experiment Station. Bulletin 295, page 426. U. S. Dept. Agr. Bulletin 41, page 14.

men and machinery is economized and work can be more promptly done. The chores are frequently done by the man not working the team, again keeping the horses in the field. It is almost impossible to keep the horses busy on a one-man farm.

If a farmer has only two horses, he cannot take advantage of the great economy that comes from driving three- and four-horse teams. Even if he could borrow the horses and machinery, he could not use them to the best advantage in his small fields. The farms of over 150 acres are the smallest ones in the counties studied that employ the equivalent of two men and five horses.

If the farmer has sons he needs enough land to provide profitable work for them else they will have to leave the farm. In Bulletin 341 of this station, the effect of the size of farm on boys leaving the farm is shown.

To make a moderate success on a small farm is much more difficult than to make a good success on a fair-sized farm. When the necessary equipment and horses for an 80-acre farm will be almost sufficient for 160 acres, and when a family can do all the work on the larger farm, it will be seen at once that the larger farm will double the income without much more expense. It therefore becomes a task for a genius on the 80-acre farm to compete with a very ordinary mortal on the larger area.

It takes much less intelligence to make a profit out of a mowing machine that cuts 50 acres a year than it does out of one that cuts 10 acres. It takes less ability to make a profit out of four horses that raise 100 acres of crops than it does to make a profit out of half as many horses that farm only 40 acres. It takes much less intelligence to direct a hired man so as to make a profit from employing him if he drives three or four horses, than it does if he drives two horses.

The above discussion applies to general farming and dairy farming, but, whatever the type of farming, the farm should be large enough to allow for the use of the well-established labor-saving practices, and large enough to provide a variety of products that make a full year's work. For truck growing, 80 acres may be as large as 300 acres in general farming. An acre partly covered with greenhouses may be an equally large business.

There is much discussion of this subject by persons who have had no farm experience or whose farm experience was gained before manure-spreaders, potato-diggers, and hay-loaders were invented. These persons usually advise little farms rather than 150- to 200-acre farms. The advice is also constantly given that farmers turn to truck growing. The supply of truck crops is easily overdone. It is usually unwise to grow truck crops unless both the soil and the markets are particularly adapted to such crops. The vast majority of our farmers must continue to produce wheat, milk, hay, oats, potatoes, and the general farm crops. Such advice

is usually given under the impression that small farms and truck crops will reduce the cost of living in cities. Under American conditions, the fair-sized farms produce farm products at least cost, so that the little farm is not desirable from any standpoint. Farmers are quick to respond whenever any type of farming promises greater profits. They change to truck growing wherever conditions warrant the change.

A farm of 1 to 20 acres makes an excellent home if one has some other source of income, but a general farm of this area is a very poor business. A farm is a place to work. The man who buys a farm buys a permanent job. If the farm is not large enough to provide a fair amount of productive work, it must of necessity be a very poor business.

RELATION OF CROP YIELDS TO PROFITS

Relation of crop yields to labor income. In order to determine the influence that yield per acre of crops has on profits, the yields on each farm were expressed on a percentage basis with 100 per cent representing the average yield of the region. The footnote to the table on page 679 gives the method of making the calculations. On some farms the larger yields are due to better soil, on others they are due to better methods of farming.

An average crop in Livingston county is better than the state average because the soils of the northern part of Livingston county are much better than the average. The yields were about 15 per cent above the averages given for the State by the Census Report.

The average yields in Livingston county for the year studied were: hay, 1.42 tons; wheat, 18.5 bushels; oats, 41.1 bushels; beans, 15.9 bushels; corn, 39.6 bushels; potatoes, 106 bushels; cabbage, 6.18 tons.

The effect of crop yields per acre on labor income is shown in Table 16 and Fig. 104. There is almost as striking a correlation between yield and profit as between size of farm and profit. Of course some persons who have large farms make large labor incomes in spite of poor crop yields, but this does not in any way disprove the importance of good yields. On the average the farmers whose crop yields dropped more than 15 per cent below the yields secured by the neighbors did not make hired man's wages.

Of 118 farms with crop yields 15 per cent or more below the average, only 7 made labor incomes of over $1000, but of 135 farms with crop yields over 15 per cent above the average, 55 made labor incomes of over $1000.

Of course, there are instances of success with low crop yields when other factors are favorable. One man who had 166 acres of land and whose crop yields were only 62 per cent of the average made a labor income of $1652, but his receipts per cow were over twice the average and he received a high price for apples. Four men with large farms

made over $3000 with crop yields 8 to 14 per cent below the average. They did well in spite of rather low yields. Others with farms of the same size and better crops did better.

TABLE 16. RELATION OF CROP YIELDS TO LABOR INCOME. 574 FARMS, LIVINGSTON COUNTY, NEW YORK*

Yields compared with average of region (per cent)	Average yield compared with average of region (per cent)	Number of farms	Labor income
75 or less	67	58	$ 16
76– 85	81	60	21
86– 95	90	102	66
96–105	101	116	57
106–115	110	103	87
116–125	120	66	95
Over 125	138	69	1,09

* If a farmer gets a small yield of hay and a large yield of oats, it is difficult to say whether his crop are good or poor. In order to make a comparison all yields must be charged to a percentage basis. Th method of figuring the percentage yield is illustrated as follows: Suppose that a farmer has 20 acres c wheat yielding 15 bushels, 30 acres of oats yielding 40 bushels, and 50 acres of hay yielding 1 7 tons. Eac of these yields is compared with the average of the region as given on page 699. The wheat yield is 8 per cent of the average. The oat yield is 97 per cent. We then have:

Acres	Per cent	Percentage times acres
20	81	1,620
35	97	3,395
50	120	6,000
105		11,015

Dividing 11,015 by 105, we find that this farmer's yields are 105 per cent. This we call the crop inde: When the total crop is given, a short way of figuring crop index is to divide the total yield of each cro by the average for that crop, add the results, and divide by the number of acres. It will be seen tha this is the same as the above method except for the order in which the operations are done.

Fig. 104 shows the labor incomes made by farmers whose crop yield were 15 per cent or more below the average and by those whose cro yields were 15 per cent or more above the average. Each cross represent one farmer and its position indicates his labor income.

The relative positions of the two entire groups show the importanc of crop yields. In each group there are great variations due to size c farms, receipts per cow, and many other factors. There is only a little cor relation between crop yields and receipts per cow or size of farm (page 672) so that these influences scatter the farms in each group but do not affec the position of the group as a whole. The scattering within the grou misleads many persons who are used to drawing conclusions from indi vidual cases. There are plenty of individuals who are doing better wit poor crops than some one else is doing with good crops. Such cases ar

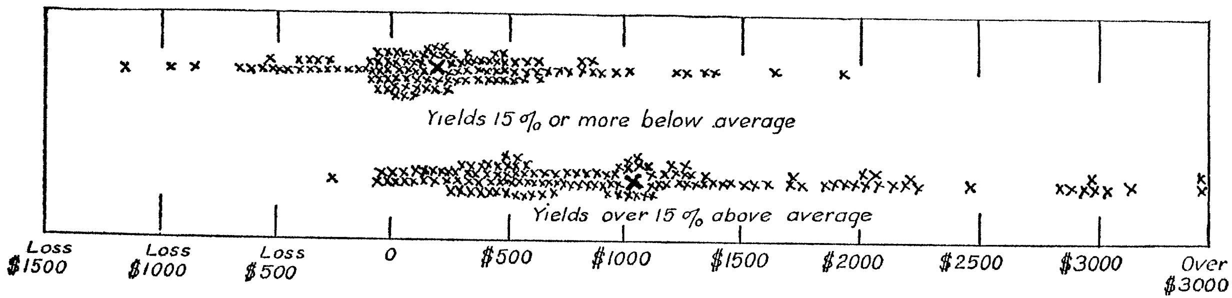

FIG. 104.— Relation of crop yields to labor income on 118 farms with crop yields 15 per cent or more below the average and on 135 farms with crops over 15 per cent above the average. The large X indicates the average. The relative position of the two groups of farms shows the importance of good crops. The scattering within the group is due to other factors. In either group there are examples of good and of poor results, but it is the position of the groups and not the results in any instance that indicates the importance of crop yields.

Comparison with Fig. 102 indicates that poor crops, while on the average just as serious as too small a farm, do not so closely limit the profits. The small farm has very little opportunity for a good profit and very little danger of large loss. With poor crops one may have very large losses if the business is large enough, and may also have a good profit if other factors are favorable, but, of course, not so large profits as a similar farm with better crops.

because of some other difference that is great enough to more than offset the result that comes from the crop yields.

Good crops are one of the primary factors affecting profits, but phenomenal crops are not necessary. Few farmers raise crops more than a third better than the average. Good crops pay, but it is not necessary to raise " two spears of grass where one grew before." Those who raise one and a fifth are doing very well. In fact, it is not probable that it would often pay to raise twice as much as the neighbors raise *on the same soil.* Farmers keep a fairly close adjustment of crop yields to prices, but, being conservative, they do not always change quite as promptly as conditions would justify them in doing. They are not so foolish as to be 100 per cent out of adjustment to conditions, as is assumed when they are advised to double their crop yields. Of course, individual instances can be cited in which such a change has paid, but instances prove nothing.

In Jefferson county, there was not quite so striking a relationship between crop yields and labor incomes. The reason for this is that the

TABLE 17. RELATION OF CROP YIELDS TO LABOR INCOME. 670 FARMS, JEFFERSON COUNTY, NEW YORK

Yields compared with average of region (per cent)	Average yield compared with average of region (per cent)	Number of farms	Labor income
75 or less	65	94	$306
76– 85	81	85	526
86– 95	91	95	618
96–105	101	103	650
106–115	111	87	662
116–125	120	67	693
Over 125	143	139	755

region depends on crops to a less extent. Probably the difference is also in part due to the kind of crops. Much more of the area is in hay. A small yield of hay may be harvested so cheaply that it may pay when an equally poor yield of a crop that required more labor would result in a loss. But, even in Jefferson county, the crop yields are next in importance to area, receipts per cow, and diversity.

Relation of crop yields to other factors. As has already been shown (page 672), the crop yields are practically the same on large and on small farms. The farmers with the best crops spend a little more for fertilizer,

but even those who got the best crops spent an average of only 60 cents per acre of crops in Livingston county and 26 cents in Jefferson county. The farmers with the best crop yields kept somewhat more live-stock than did those with the poorer yields. The farms that gave the best crop yields had an animal unit for each 3.4 acres of crops in Livingston county, and one for each 2.2 acres of crops in Jefferson county. The percentage of receipts from cash crops was about the same in each group. The better crops enable the farmers to keep more live-stock and yet sell as large a proportion of cash crops as are sold on the farms with poorer yields. In Livingston county the receipts per cow had no relationship to the crop yields. In Jefferson county the returns per cow were a little better on the farms that got the best crops. The amount of work accomplished per man or horse is just the same on the farms getting good crops as on those getting poor crops. The good crops do not come from working fewer acres per man or horse.

Comparative influence of crop yields and size of farm on profits. Crop yields are a very important factor affecting profits, but their importance has often been over-emphasized. Yields are only one of the limiting factors. Unfortunately the almost universal method of emphasizing the importance of yields is to disparage the importance of number of acres. The size of business is fully as important as yields. It is not necessary to deny the importance of either one in order to prove the importance of the other. One of the oft-quoted axioms that is about as misleading as most axioms is that the farmer should "farm fewer acres and do it better." We have already seen that the larger farms raise crops as good as the small ones. There is no necessity for reducing the size of farm below the area that is adapted to modern machinery in order to raise better crops. The advice to farm better is good, but it is a mistake to assume that this calls for fewer acres.

Table 18 shows in a most striking way the combined influence of size of farm and crop yields. With any given size of farm, the labor incomes increase very rapidly as crop yields increase. If the crops are very poor (more than 15 per cent below the average), there is usually little profit with any size of farm. If crop yields drop so low that they are raised at a loss, more acres would not help matters. But with average crops, the profits increase rapidly with size of farm.

The farms of 50 acres or less did not do very well even if they did have good crops. The farms of 51 to 100 acres with the best crops made more than the farms of 101 to 150 with average crops, but not nearly so much as the farms of over 200 acres with average crops.

Farms of 101 to 150 acres with the best crops made more than did farms of 151 to 200 acres with average crops, but not much more than half as much as did farms of 151 to 200 acres that also had the best crops.

A comparison of Figs. 102 and 104 shows that area sets a more positive limit on profits than do yields. The farms of a given area are grouped more closely about the average than are the farms with given crop yields. This should be expected. With a given area, one soon reaches the limit of crop production. He cannot get yields of five to ten times the average. But with given crop yields, there are some farms over five to ten times as large as others.

TABLE 18. RELATION OF SIZE OF FARM AND CROP YIELDS TO LABOR INCOME. 574 FARMS, LIVINGSTON COUNTY, NEW YORK

Acres	Crop yields compared with average of region		
	85 per cent or less	86 to 115 per cent	Over 115 per cent
	Labor income	Labor income	Labor income
50 or less	$ 29	$ 321	$ 355
51–100	185	427	656
101–150	94	592	985
151–200	449	934	1,749
Over 200	266	1,056	1,773

Conclusions on crop yields. Usually the most profitable way for the individual farmer to secure good crops is to get a farm that has a naturally rich soil. It is usually much cheaper to buy fertility in the soil than to buy poor land and spend years and money in making it productive.

With any given soil, the crops may be increased by saving the farm manure and by spreading it thin enough with a manure-spreader so that the entire farm can be covered frequently, every five years if possible. It is much better to spread five loads per acre every five years than to spread ten loads every ten years.

The use of more fertilizers, lime, tile drains, better methods of tillage, and better crop rotations may also be called for. Which of the various means of securing good crops to use, and just how far to go with one before improving on some other point, is a problem that taxes the best judgment of the most experienced farmer. Certainly it does not pay to go on permanently raising crops that are poorer than the neighbors raise. If the results in the entire neighborhood are too low because of poor soil, it may be best to change the type of farming or to go elsewhere. There is no more reason for working a farm that cannot be made to pay than there is for working the abandoned iron mines in New York that cannot be made to pay.

Apparently a farmer would do well to use some means by which he can ;ain yields a little better than his neighbors obtain *on the same soil.* out a fifth better seems to be a good standard to work for. If the ghbors raise one ton of hay, it is probable that it will pay to raise at st 1.2 tons. If they raise 1.5 tons, it is probable that 1.75 tons will y better. But on the soil that normally raises 1.5 tons, it is probable it 3 tons can be raised at less cost per ton on two acres than on one. short, it is usually not wise to go too far beyond the natural limitations the soil. Certainly this is the opinion of the farmers. The highest p index in Livingston county was 186 per cent. There was no farmer ose crops were twice as good as the average. There were, of course, tances of a single crop being as good as that, but, taking all the crops gether, 86 per cent above the average was the highest yield obtained. is farm had a soil that was naturally extra good.

RELATION OF PRODUCTION OF ANIMALS TO PROFITS

Receipts per animal. If a farm keeps many animals, the returns from em are of course just as important as are the crop yields. The products d from the average cow little more than pay for the feed. But the lue of the feed in New York is usually only about 55 to 70 per cent of e total cost of keeping a cow. There can be no profit from keeping average cow with the present prices that farmers receive for their iry products. The prices of products ought to be high enough so that average cow would pay interest and wages to the farmer. But the neral question as to price of milk is not a matter that any individual rmer can settle. The purpose of this bulletin is to help individuals th their personal problems. The individual must take the price offered, d, if he is to make a profit, must adjust his business accordingly. There no surer way of losing money than to feed cows that do not pay their ed bill.

The average receipts per cow from milk and its products were $53 in ompkins county, $57 in Livingston county and $59 in Jefferson county. his is in addition to milk used for the few calves raised and in addition milk used in the home. When all feed is counted and the entire value milk and stock is counted, the average cow pays her feed bill, but e manure does not begin to pay all other costs. Evidently one must ve cows much better than the average in order to make money.

The receipts per cattle unit averaged $52 in Tompkins county, $52 Livingston, and $57 in Jefferson. This includes returns from all sources r the entire cattle industry. This indicates that the returns from ising and selling cattle do not greatly change the results.

When all animals except horses are included, the results are little changed, the receipts per animal unit except work horses being $52 for Tompkins county, $50 for Livingston, and $61 for Jefferson.

Relation of receipts per cow to profits. Table 19 shows the relation of the receipts per cow to profits on farms in Jefferson county having

TABLE 19. RELATION OF RECEIPTS PER COW FROM MILK AND ITS PRODUCTS TO PROFITS ON 585 FARMS WITH SIX OR MORE COWS. JEFFERSON COUNTY, NEW YORK

Receipts per cow	Average receipts per cow	Number of farms	Labor income
$30 or less	$ 22	45	$ 241
31– 50	42	178	394
51– 75	63	221	764
76–100	86	111	909
Over $100	119	30	1,307

six or more cows. Not until the receipts per cow reach $75 do the cows aid the farmer in making a profit. Efforts to raise the receipts per cow are worthy of the most serious attention. There were 223 farmers in Jefferson county who sold less than $51 worth of milk and its products per cow. If these farmers cannot find a way to get better returns, it would pay them to sell their cows and either keep some other kind of livestock or else not keep any.[7]

The size of the farms is practically the same in each group of receipts per cow. The rate of work of men and horses is also practically the same. The men who get the best returns per cow are not reducing the number of cows per man. The crop yields are a little better on the farms getting the highest returns per cow. This would help to raise the labor income. The percentage of receipts from crops is lowest on the farms that secured the best returns per cow. As we shall see later, this tends to reduce the profits. This will probably offset the effect of better crops, so that the higher labor incomes are probably the direct result of the returns per cow.

Better cows and better feeding are the two chief differences that result in better returns per cow. Weighing the milk from each cow, cow-testing associations, and methods of feeding are worthy of much more attention in every county studied. Bulletins and advice on these subjects are readily available.

[7] Cornell University Agricultural Experiment Station. Bulletin 295, page 484.

The number of calves raised is not strikingly different in the different groups. Those with the poorest returns are raising a little larger proportion of their calves.

The extent to which the farmers are buying cows is about the same in the first three groups. They replace about 1 cow in 23 by purchase each year. Those who get returns of $76 to $100 per cow are doing more buying and selling. Those who secured returns of over $100 per cow are doing the most buying and selling. Each year they replace one seventh of the herd by purchase and one eighth with heifers raised. They are changing cows almost twice as fast as is the average dairyman. They depend more on purchased cows than do those who get poorer returns. This is exactly contrary to the popular statement that in order to be successful a dairyman must depend on the calves raised by himself.

By purchase and by heifers raised the farmers who got returns of less than $76 per cow replaced one seventh of the herd in the year. Those who got returns of $76 to $100 replaced one fifth of the herd. Those who got returns of over $100 replaced over one fourth of the herd (28 per cent) in the year.

Sixty per cent of the farmers who received over $100 per cow kept pure-bred and 30 per cent kept high-grade Holstein bulls. The proportion of pure-bred and high-grade bulls decreased as the receipts per cow decreased.

Some farmers are selling the wrong kind of dairy product. A few farmers are making butter on the farm to be sold at wholesale prices. Few of these are getting good returns per cow or are making good labor incomes if they depend very largely on the dairy. It is very difficult to make a profit from homemade butter sold at ordinary prices. Those who sell to creameries to be made into butter are doing better, but the returns from this source are not very high. When one lives near enough to a milk-shipping station or lives on a milk route so that the milk can be hired hauled, market milk usually pays best. However the product is sold, if the receipts are not $75 to $100 per cow the farmer should study his dairy conditions in order to see whether he can increase the returns, and if they cannot be increased he may well question the advisability of continuing in the dairy business. Near New York City, where feed and milk are both higher in price, the returns should be better in order to make the business pay.

There is a much greater variation in the production per animal than in the crop yields on different farms. The farmer has a much fuller control of the factors that determine the production of the animals than of those that determine the crop yields. If a farmer does his part in selection, care, and feeding, he may expect returns from his animals of

nearly double the average. But whatever one may do, his crops may be limited by drought, frost, or other unfavorable conditions that are beyond his control. Because of these uncertainties, a good farmer usually finds that it pays to do his part for a production per animal of at least fifty per cent above the average, while he may not strive for crops that exceed the average by more than half this amount.

For further discussion of this and the returns from other kinds of animals, see Bulletin 295 of this station, pages 473–502.

Relation of size of farm, crop yields, and receipts per cow to profits. The effect of various combinations of good and poor crops with large and small farms has been shown on pages 682 to 683. When we add the third factor of good cows, a still more striking correlation is shown. Table 20 gives such a comparison. Each of the factors is of great importance.

TABLE 20. RELATION OF SIZE OF FARM, RECEIPTS PER COW, AND CROP YIELDS, TO LABOR INCOME ON 585 FARMS WITH SIX OR MORE COWS, JEFFERSON COUNTY, NEW YORK

	Acres		
	100 or less	101–150	Over 150
	Labor income	Labor income	Labor income
Receipts per cow $50 or less			
Crop index 85 per cent or less	$308	$ 273	$ 331
Crop index 86–115 per cent	381	482	424
Crop index over 115 per cent	158	415	413
Receipts per cow $51–$75			
Crop index 85 per cent or less	304	590	669
Crop index 86–115 per cent	437	653	1,017
Crop index over 115 per cent	537	636	1,161
Receipts per cow over $75			
Crop index 85 per cent or less	594	935	1,233
Crop index 86–115 per cent	641	1,038	1,148
Crop index over 115 per cent	659	1,124	1,291

Size of farm and receipts per cow are about equally important. Each of them is more important than yields per acre in Jefferson county. Raising the cows from the middle to the best group has the same effect as raising the size of farm from the middle to the largest group. The crops must be changed from the lowest to the best class in order to have an equal effect.

No one of the factors results in a good labor income if the other factors are poor. A combination of good cows and good crops with a small farm does not give a good labor income, but of course is better than a small

farm with poor cows and poor crops. A large farm does not bring good results if the cows and the crops are poor. There are seven different combinations that resulted in average labor incomes of over $1000:

A large farm with medium cows and medium crops.
A large farm with medium cows and good crops.
A medium-sized farm with good cows and medium crops.
A medium-sized farm with good cows and good crops.
A large farm with good cows and poor crops.
A large farm with good cows and medium crops.
A large farm with good cows and good crops.

Of course the farms that had good cows, good crops and a large area did best.

PROPORTION OF INCOME FROM CASH CROPS AND FROM ANIMALS

Relation of cash crops to profits. Farmers who maintain a good balance between cash crops and animal products make more than do those who go to either extreme. In Jefferson county those who sold no crops made little more than half as much as did those who derived half their income from cash crops. But those who derived more than 60 per cent of their income from the sale of crops also made less than did those who kept a good balance, as is shown in Table 21. The returns per cow are much

TABLE 21. RELATION OF PROFITS TO PROPORTION OF THE INCOME FROM CROPS. 670 FARMS, JEFFERSON COUNTY, NEW YORK

Per cent of receipts from crops	Average per cent from crops	Number of farms	Receipts per cow from milk and its products	Work units per man	Labor income
0	0	81	$61	243	$412
10 or less	4	201	65	248	546
11–20	16	111	60	247	653
21–40	30	180	57	252	692
41–60	49	65	50	236	781
Over 60	76	32	32	168	536

better on the farms that derive the least from cash crops, so that the better returns on the diversified farms are in spite of the poorer cows. Cash crops, therefore, appear to be even more important than the table indicates.

The poorer the cows, the more important it is that crops be sold. The farmers who have the best cows sell the least crops. But even with the best cows, those who sell some crops are doing better than those who sell no crops, as is seen in Table 22. The conclusions agree with the results

TABLE 22. RELATION OF RECEIPTS PER COW AND CASH CROPS TO PROFITS ON 585 FARMS WITH SIX OR MORE COWS. JEFFERSON COUNTY, NEW YORK

Per cent of receipts from crops	Receipts per cow from milk and its products		
	$50 or less	$51-$75	Over $75
	Labor income	Labor income	Labor income
No crops sold	$ 56	$ 571	$ 926
1-20 per cent	311	589	962
21-40	426	947	1,183
41-60	554	1,366	*
Over 60	599	*	†

* Only two farms in this group.
† No farms in this group.

for Tompkins and Livingston counties. (See Bulletin 295 of this station, pages 503 to 510.)

The amount of capital must also be considered in determining the amount of animal products to sell. Table 23 shows that the farmers

TABLE 23. RELATION OF CAPITAL TO CASH CROPS. 578 FARMS, LIVINGSTON COUNTY, NEW YORK

Capital	Per cent of receipts from crops	Per cent of receipts from stock and stock products
$ 5,000 or less	73	27
5,001- 7,500	68	32
7,501-10,000	65	35
10,001-15,000	65	35
15,001-20,000	55	45
Over 20,000	43	57

with small capital are selling more crops, and that as the capital increases the sales of animal products become more important.

In each capital group there are farmers who are trying all degrees of live-stock and crop farming. Table 24 shows that with small capital

TABLE 24. RELATION OF CAPITAL AND CASH CROPS TO PROFITS. 578 FARMS, LIVINGSTON COUNTY, NEW YORK

Per cent of receipts from crops	Capital		
	$5,000 or less	$5,001–$15,000	Over $15,000
	Labor income	Labor income	Labor income
20 or less	$253	$399	$1,000
21–40	181	411	1,399
41–70	256	624	1,038
71–90	424	623	1,194
Over 90	231	497	473

those who depend largely on cash crops make the most, while with larger capital those who derive only 21 to 40 per cent of their income from crops are doing best. This is what one would except. Live-stock represents added capital after one has bought and equipped his farm. If one is short of money, the absolutely essential things are land, machinery, and horses. One may get along without live-stock, but one cannot farm without land and equipment. The majority of farmers understand this principle. When they get more money, they increase the amount and improve the quality of their live-stock.

Acres of crops per animal unit. Another way of comparing farms is on the basis of number of acres of crops grown for each animal unit kept. An animal unit is a cow or a horse, or the equivalent in young stock or other animals, as defined on page 667. Crops grown include all harvested crops, but do not include pasture or woods. All the farmers had pasture in addition. In Jefferson county there were no farmers who kept more than one animal unit for each acre of crops grown. More than half of the farmers kept an animal unit for each 1 to 3 acres of crops. The farms that were most heavily stocked secured the best crop yields, but did not make the best labor incomes The best labor incomes were made by those who did not go to either extreme — the ones who had their farms moderately well stocked, as is shown in Table 25. Some of the reasons for the better results by those who avoid either extreme will be given later.

The amount of stock that it pays to keep of course depends on the returns that one gets from it. With very poor stock, the less one has

TABLE 25. RELATION OF ACRES OF CROPS PER ANIMAL UNIT TO LABOR INCOME AND CROP YIELDS. 670 FARMS, JEFFERSON COUNTY, NEW YORK

Acres of crops per animal unit	Number of farms	Crop yields compared with average of region (per cent)	Labor income
1.0–2.0	165	123	$580
2.1–3.0	229	104	597
3.1–4.0	131	93	601
4.1–5.0	64	88	721
Over 5.0	81	91	627

the better. The better the stock, the more heavily the place should be stocked. With good stock in Jefferson county, it pays best to have an animal unit for each 3 to 4 acres of crops (Table 26). The exact amount

TABLE 26. RELATION OF ACRES OF CROPS PER ANIMAL AND RECEIPTS PER ANIMAL UNIT TO LABOR INCOME. 670 FARMS, JEFFERSON COUNTY, NEW YORK

Acres of crops per animal unit	Receipts for each animal unit except horses		
	$50 or less	$51–$75	Over $75
	Labor income	Labor income	Labor income
1.0–2.0	$210	$649	$ 895
2.1–3.0	264	680	971
3.1–4.0	314	763	1,053
Over 4.0	378	824	914

to keep will of course vary in different regions and on different farms, but nearly always a diversified farm pays better than does a farm that goes to either extreme.

Reasons for larger profits on diversified farms. There are many reasons why it does not pay to go to the extreme either way. Ordinarily a man can raise feed for more cows than he can milk. If each man milks 10 to 15 cows, he can raise the hay and silage for these cows and part of the grain, and in addition will have time to raise hay, potatoes, cabbage, or other crops for sale. If the cows are so poor, or prices of the product so low, that the cows do not pay a good price for their feed, it is of vital importance that cash crops be raised. Even if the cows are so profitable that they pay more than market price for their feed, it still pays to raise

cash crops, because these crops can be raised at very little additional cost. It might be suggested that more cows be kept to eat the additional crops, but this calls for more men who in turn can raise additional crops, for practically always the men can raise more crops than enough to feed the cows that they can milk. This question is fully discussed in Bulletin 295 of this station, pages 506 to 524.

There are other reasons why diversified farms pay best. If a dairyman keeps all the cows he can feed in a good year, he will have to buy hay in a poor year. On such years hay is usually very high in price, but the price of milk usually does not change much. Either he must buy high-priced hay or sell some of his stock. It usually pays to keep no more stock than one can raise hay and silage for in a rather poor year. This allows some roughage to sell in good years. Hay and roughage are so expensive to handle that one must study his conditions carefully before he decides to buy hay regularly. Diversified farming lessens the risk.

If a farm is too heavily stocked the returns from manure are not so good. The thinner manure is spread, the more the returns per load of manure. At the Pennsylvania Experiment Station a test of this has been running for many years. Manure is applied every other year at the rates of 6, 8, and 10 tons per acre. For twenty-five years the average values of the increased crop per ton of manure were[8]:

6 tons applied every two years...........	$2.16 per ton
8 tons applied every two years..........	1.66 per ton
10 tons applied every two years..........	1.44 per ton

A similar test is being conducted in Ohio. Manure is applied once every three years. The average value of the increased crops per ton of manure for seventeen years were[9]:

4 tons applied every three years.................	$3.48
8 tons applied every three years.................	2.70
16 tons applied every three years................	2.24

An animal unit usually produces a little over a ton of manure a month. Much of this is produced at pasture. If all the manure around the barns is saved, it will usually amount to 6 to 9 tons per animal unit kept on a New York farm. If an animal unit is kept for each three acres of crops, and if all the manure is saved, there will be enough to cover all the cropped land with about 6 to 9 tons per acre every three years.

A very large amount of the manure is lost, so that what should be one of the important returns from live-stock becomes of less consequence.

[8] Pennsylvania Agricultural Experiment Station. Bulletin 90, page 23.
[9] Ohio Agricultural Experiment Station.

Some persons who would not think of selling hay, for fear of losing fertility, will allow half the manure that they get from feeding it to be wasted. The farm is no better off than it would be if they sold half the hay and saved all the manure.

A large proportion of the animal products that go on the market are produced from low-grade feed. Animals are kept to fill out the year's work. Stock is often kept in order to make use of pasture land that could not otherwise be used. Much of the work is sometimes done by women and children. For all these reasons, live-stock is produced on a close margin of profit. The results of cost accounts show that, for the time spent, crops usually give much higher pay for a day's work than do animals. It usually pays to spend at least part of the time raising cash crops that pay good returns for a day's work.

If one goes to the other extreme and keeps no animals or too few animals he will not have a full year's work. Animals help to provide winter work. Table 21 shows that when over 60 per cent of the money comes from cash crops, a man accomplishes only two thirds as much in a year as he does when more animals are kept. It is best to raise cash crops when they pay well, but the year should be filled out with other work even if the pay per day is less.

Every farm has a considerable amount of low-grade hay, mixed hay, and other products that do not have much market value or that are too bulky to pay to sell. At least enough stock should be kept to make use of these low-grade products. On most farms there is some land that will not pay for farming but that will bring some income as pasture land.

Whatever explanation one may make of the reasons for diversified farming, the facts remain the same. In every county studied, the persons who have a good balance between cash crops and animal products are making more than are those who go to either extreme. Usually, in New York, 20 to 40 per cent of the receipts should be from the sale of crops. The more money one has and the more profitable his animals are, the nearer he should come to an exclusively stock farm, but it rarely pays to stop selling at least one cash crop. The less money there is available and the poorer stock pay, the fewer one should keep, but it rarely pays to sell nothing but crops even on a truck farm.

Usually a farm should have two to four important products, and usually at least one of these should be an animal product and at least one should be a cash crop. Diversified farming is often spoken of as farming where one has a little of everything. The writer doubts the value of an indefinite collection of things all so small that they are likely to be more or less neglected, but all investigations indicate the desirability of having two to four products to sell, each one of which is so important that it is not neglected.

IMPORTANCE OF A WELL-BALANCED FARM

All the preceding discussions indicate that it is not merely good cows, good crops, and a good-sized farm that need attention, but that when one has improved one of these he should give attention to the others. Farmers are just like all other persons — they are likely to have hobbies. The man with good cows is likely to become so proud of his cows that he neglects his crops. The man with good crops sometimes neglects his stock. Very often attention is given to increased production when a larger business is the most important point to be considered.

There are very few farms that are good in each of the above three points. In the region in Jefferson county there were 16 farms that had receipts per cow of $75 or more, that raised 100 acres of crops or more, and that had crops as good as, or better than, the average. The average labor income on these farms was $1497. The lowest labor income was $733.

In order to have a figure that will compare farms when size, receipts per cow, and crop yields are given equal weight, a figure was calculated for each farm representing its comparison with the average farm. The average size is called 100 per cent. The average receipts per cow and the average crop yields were each called 100 per cent. On this basis the percentages representing size of farm, receipts per cow, and crop yields for each farm were calculated. These three percentages were then multiplied together to get a single figure representing the farm.[10] If a farm is of average size, gets average crops, and has cows twice as good as the average, it is represented by 200 per cent. If a farm has average crops and is twice as large as the average, but has cows only half as good as the average, it is represented by 100 per cent. Table 27 shows a comparison of farms sorted in this way.

TABLE 27. COMPARISON OF FARMS WHEN AREA, CROP YIELDS, AND RECEIPTS PER COW ARE GIVEN EQUAL CONSIDERATION. AVERAGE FARM EQUALS 100 PER CENT. JEFFERSON COUNTY, NEW YORK

Comparison with average (per cent)	Number of farms	Labor income
30 or less	57	$ 95
31–40	45	182
41–50	58	221
51–60	56	300
61–70	62	390
71–80	56	507
81–90	38	568
91–100	34	644
101–200	199	842
Over 200	62	1,596

[10] In making this calculation a much shorter way of calculating was used, but the method given above shows the principles involved.

SOME TYPICAL FARMS

If any further proof is needed to show that the four points thus far discussed are the primary ones that determine the profits on most farms, it is furnished by the fact that, when these four points are given, one can estimate the labor income with approximate accuracy in about 80 per cent of the cases. There are many other things that may influence profits, but the fact is that, in the majority of cases, no other point does have an influence strong enough to overcome the effect of these four things. Of course, the other factors cause minor variations on all farms. A few examples from Jefferson county will illustrate the point. The average farm had 73 acres of crops, received $59 per cow from milk and its products, derived 22 per cent of the income from the sale of crops, and made a labor income of $609.

Farm 1:

Acres of crops, 29, very poor
Yields compared with average, 208 per cent, excellent
Receipts per cow from 11 cows, $116, excellent
Percentage of receipts from crops, 21 per cent, excellent
Labor income, $980

This is the best record for either a general or a dairy farm with so small an area. It represents the best record of a "little farm well tilled." Splendid crops, splendid cows, good diversification, and all the work done by the farmer himself with two months of hired labor. It would be very hard to give any suggestions for improvement except that the farm be enlarged. Such a farmer should be able to make a labor income of $3000 a year if he bought or rented enough more land so that he could raise 100 more acres of crops. He would then keep more cows and keep two men by the year.

Farm 2:

Acres of crops, 21, very poor
Yields compared with average, 211 per cent, excellent (hay 3.3 tons, silage 13 tons)
Receipts per cow from 8 cows, $90, excellent
Percentage of receipts from crops, 22 per cent, excellent
Labor income, $380

This farmer had a little less land, had fewer and not quite so good cows, and kept a hired man by the year. For these reasons he made less than the preceding one.

Farm 3:

Acres of crops, 133, good
Yields compared with average, 75 per cent, poor (hay 1.1 tons, oats 25 bushels)
Receipts per cow from 20 cows, $95, excellent
Percentage of receipts from crops, 16 per cent, fair
Labor income, $1661

This farmer gets crops only three fourths as good as the average, but with the large area he should make a fair profit from growing them. He sells part of his crops and gets good returns for what he feeds to cows. His crops are about one third as good as those of the first two farms, but the larger area much more than makes up the difference. With crops as good as his neighbors, he might readily bring his labor income to $2000 or more. The next farm shows what might be expected with better crops.

Farm 4:

Acres of crops, 110, excellent
Yields compared with average, 142 per cent, excellent
Receipts per cow from 26 cows, $96, excellent
Percentage of receipts from crops, 19 per cent, excellent
Labor income, $2239

This farm is excellent in every particular. We should expect it to make a labor income of over $2000, as it does. The reason why it makes more than the preceding farm is because of better crops.

Farm 5:

Acres of crops, 109, excellent
Yields compared with average, 120 per cent, excellent
Receipts per cow from 32 cows, $56, poor
Percentage of receipts from crops, 4 per cent, poor
Labor income, minus $113

This farmer made very good profits on his crops, of which he had a good acreage. But he fed these crops to cows that did not pay for their feed. If he had sold most of his crops he would have done well. The farm is too heavily stocked even for good cows. Fewer and better cows and the sale of more cash crops would readily make the labor income $1500, but as it is, the farmer did not even make interest on his capital. He paid for the privilege of working.

Farm 6:

Acres of crops, 112
Yields compared with average, 104 per cent
Receipts per cow, $76
Percentage of receipts from crops, 27 per cent
Labor income, $1035

This farm is making much more than the average by having a little more crops and having cows much better than the average. The crop yields, returns per cow and area in crops could all be increased to advantage. Unless better cows are kept, it might pay to sell more crops, but an improvement in cows would be better. The following farm shows what might be expected with a larger area in crops:

Farm 7:

Acres of crops, 253
Yields compared with average, 104 per cent (hay 1.4 tons, oats 37 bushels, silage 12 tons)
Receipts per cow from 30 cows, $75
Percentage of receipts from crops, 48 per cent
Labor income, $2859

The primary difference from the preceding farm is in having over twice the area in crops. It makes over twice the labor income. The crop yields and the receipts per cow should be improved. The next farm shows what might be expected with better crops:

Farm 8:

Acres of crops, 259
Yields compared with average, 134 per cent
Receipts per cow from 32 cows, $74
Percentage of receipts from crops, 53 per cent
Labor income, $3270

In three counties, this is the second highest labor income found for any farmer who sold milk at wholesale prices. The one point in this farm that needs strengthening is the returns per cow. The farm that made a better labor income had better cows.

THE MOST SUCCESSFUL DAIRY FARMS

In the 16 townships studied in Tompkins, Livingston and Jefferson counties, there were 23 farms that sold milk at wholesale and that made

labor incomes of over $2000. The averages for these farms are given in Table 28.

These farms had an average of 257 acres, 154 of which were in crops. The smallest one had 144 acres of land with 81 acres in crops. The largest had 487 acres of land with 286 acres in crops. They kept an average of 32 cows. On the average they furnished work for 3.2 men including the operator. Their average capital was $19,728.

They derived one third of their income from the sale of cash crops. None of them was an exclusively dairy farm. Only one derived less than one sixth of the income from cash crops. This one raised all the feed used, and sold $275 worth of crops.

The crop yields averaged nearly one fifth better than the neighbors' crops. Only 6 of the 23 farms had crops poorer than the average.

The receipts per cow from the sale of milk averaged $98. Only one farm had cows as poor as the average.

The majority raised their own cows, but 11 of the 23 bought some cows. Four depended entirely on purchased cows, and four others purchased more cows than they raised.

Six bought no feed of any kind. Nine bought less than $10 worth per animal unit kept. Seven bought $10 to $20 worth and one bought over $20 worth per animal unit. The amount spent for feed averaged $7 per animal unit. All these farms are in regions well adapted to crop-raising. Dairymen nearer New York City buy more feed because the amount of land that is well adapted to raising feed is very limited.

Eighteen of the 23 farms raised silage, 15 raised corn for grain, all raised hay, 21 raised oats, 13 raised wheat, 2 raised buckwheat, 5 raised cabbages, 10 raised beans, 11 raised four or more acres of potatoes. The average yields for the farms growing each of these crops are given in Table 28. Apples and some other crops were raised by a few of the 23 farmers.

The amount of work accomplished per man and per horse was much above the average. The cost of machinery per acre of crops was lower than the average. The proportion of capital invested in houses and barns was lower than the average, as was the value of barns per animal unit. By comparing with Tables 8, 9, 11 and 12, it will be seen that in each case these differences are due to the size of farm, as these farms correspond very closely with the average for the large farms.

The primary difference between these successful farms and the average large farm is in the receipts per cow and the crop yields. Being large farms, they have the many advantages of such farms. They combine good production and diversification with these advantages.

EFFICIENCY FACTORS

Table 28 gives some of the more important efficiency factors for each county. It also includes similar factors for the 23 most successful dairy

TABLE 28. EFFICIENCY FACTORS. AVERAGES FOR TOMPKINS, LIVINGSTON, AND JEFFERSON COUNTIES, AND FOR 23 MOST SUCCESSFUL FARMS SELLING MILK AT WHOLESALE

	Tompkins county	Livingston county	Jefferson county	23 most successful wholesale* milk farms
Labor income	$445	$666	$609	$2,658
Size of business				
Capital	$5,712	$12,037	$9,006	$19,728
Area (in acres)	108	149	143	257
Acres in crops	57	93	73	154
Number of work horses and mules	3.1	5.6	3.4	7.4
Number of cows	8	9	15	32
Number of other animal units	5	9	6	8
Total animal units	16	23	24	47
Number of men including operator†	1.5	2.2	1.7	3.2
Productive units of man work	301	479	421	942
Productive units of horse work	177	337	219	550
Production				
Crop yields compared with average (per cent)	100	100	100	119
Corn (bushels per acre)	29.5	39.6	36.4	48.0
Corn silage (tons)	... .	9.8	9.9	11.8
Oats (bushels)	32.4	41.1	30.8	43.0
Wheat (bushels)	20.9	18.5	19.8	23.5
Buckwheat (bushels)	16.6	......	......	21.4
Timothy and clover hay (tons)	1.3	1.42	1.44	1.59
Potatoes (bushels)	122	106	124	153
Beans (bushels)	....	15.9	18.0	21.6
Cabbage (tons)	....	6.18	8.34	10.3
Pounds of milk sold per cow	....	....	....	‡6,470
Receipts per cow from milk and its products	$53	$57	$59	$98
Receipts per cattle unit	$52	$52	$57	$92
Receipts per sheep	$5.18	$4.87	$8.91	$5.33
Receipts per animal unit except work animals	$52	$50	$61	$90
Percentage of receipts from crops	40	58	22	34
Efficiency in use of labor				
Crop acres per man	38	42	43	48
Animal units per man	11	10	14	15
Productive work units per man	201	218	248	294
Crop acres per horse	18	17	21	21
Productive work units per horse	57	60	64	74

* Three other dairy farms that sold milk at wholesale and that made over $2000 labor income were omitted. One derived nearly all its income from buying and selling cattle. One made most of the income from pure-bred stock. One was really a crop farm.

† Work of women and children is included on the basis of the time that it would take a man to do the same work.

‡ This is in addition to milk used in raising calves and milk used in the house. The total production probably averages nearly 7000 pounds.

TABLE 28—(*continued*)

	Tompkins county	Livingston county	Jefferson county	23 most successful wholesale* milk farms
Efficiency in use of capital				
Value per acre	$43	$72	$51	$62
Percentage of area in crops	53	62	51	60
Value of houses	....	$1,658	....	§$2,238
Percentage of capital in houses	....	14	....	11
Value of barns	....	$1,603	....	§$2,663
Percentage of capital in barns	....	13	....	14
Value of barns per animal unit	..... .	$70	....	$57
Percentage of capital in all buildings	45	27	....	25
Value of machinery	$407	$583	$482	$968
Value of machinery per acre of crops	$7.14	$6.27	$6.60	$6 29
Fertility				
Crop acres per animal unit	3 6	4.0	3.0	3 3
Amount spent for fertilizers	$15	$51	$10	$39
Cost of fertilizers per acre of crops	$0 26	$0.55	$0 14	$0.25

§ Values of houses and barns for 16 of the 23 farms.

farms that sold market milk at wholesale. By the use of these and similar factors for other points, and with the other knowledge gained from the study of the records of large numbers of farms, it is possible to analyze the farm business and see which points are most in need of attention and which things are already good. When studying a particular farm, reference should also be made to the other tables in order to see whether the conditions on the farm are due to good or bad management or whether they are the natural results for a farm of the same size. Comparison is also made with farms having the same receipts per cow, crop yields, and other factors.

CONCLUSIONS

Of course, there are other important factors for success in farming, but on the great majority of farms the area in crops, the yield of these crops, the returns per animal, and the diversity of the business are the most important factors. Mistakes can, of course, be made on many other things. But the practical farmer who has these four factors good rarely makes such serious mistakes on other things as to fail to do well.

For efficient farming in New York an investment of $10,000 to $20,000 is usually necessary. In States where land is higher in price a larger amount is needed. Occasionally a farmer does well with a capital of $5000 or even less, but such instances are not numerous. With less than $10,000 it is usually necessary to work with very inadequate equip-

ment, poor stock and too little land. The capital need not all be owned by the farmer. The land and some of the stock may be furnished by a landlord, so that the tenant farmer need not have a very large capital. One who owns a farm may borrow part of his capital or may own some land and rent additional land.

Most of the profitable general or dairy farms have 150 to 300 acres of land, with 100 to 200 acres of crops. For these kinds of farming, 80 to 100 acres of crops is about the minimum area that will make good use of a fair equipment and the horses that go with it. Better equipment can be used and very much better use of it can be made with 150 acres of crops. With these types of farming, 600 acres is about the limit that can be run from one center, and it is not often that such a large area can be handled to advantage. When public welfare and the prosperity of the farmer are both considered, farms of 150 to 300 acres seem to be the best size for general and dairy farms. In regions where less than half the land is tillable a correspondingly larger area is needed. If a farmer does not have land enough and if he cannot buy more, it is often possible to rent additional land so that he can get full use of his horses, machinery, and labor.

Some farmers whose crops are below the average do very well, but those who make the highest profits usually have crops that are better than their neighbors raise. Apparently it pays to raise crops at least a fifth better than the neighbors raise on the same soil.

On dairy farms there is no factor more important than the receipts per cow. In the three counties studied, the cows must be about a half better than the average if they are to contribute to the success of the farm. The most successful farmers usually get returns from a half better to nearly twice as good as the average.

A well-balanced combination of cash crops and live-stock usually pays better than does either extreme. The best combination varies with the amount of money that the farmer has, with the quality of the live-stock kept, and with the profits that come from crops. Even with very profitable live-stock it nearly always pays to have some cash crops. One should be very sure that he is right before he allows the sale of cash crops to drop below a fifth of his total sales. On the other hand, unless the returns from live-stock are very poor or unless the amount of money is very limited, it usually pays to get at least half of the income from stock.

Ordinarily there should be three or four important products sold — that is, three or four products, no one of which is neglected because of the others.

The highest excellence in one particular does not insure a good income. No matter how good the cows and crops, if the farm is too small the

income is not likely to be large. With a large farm and good crops, the returns will not be good if the crops are fed to live-stock that brings poor returns.

If a farmer is doing well in one of the above points but not so well in some of the others, he is likely to get greater returns for a given effort by strengthening the weak points rather than by spending more effort on the thing that is already good. It is better to have a well-balanced farm than to excel ever so much in one particular and neglect other equally important points.

Other points often prevent the profits from rising as high as they might go if the entire business were well balanced. The wrong kind of farming is sometimes followed. Inconvenient buildings, a poorly-laid-out farm, or failure to plan the work ahead may lose time. There may be too much or too little equipment. Occasionally too much is invested in buildings or too many horses are kept, or any one of many other factors may be wrong. But in the great majority of cases, if the four factors here emphasized are good the other mistakes made by experienced farmers are not sufficient to prevent at least a fair profit. When these four points are good, a mistake in having an extra horse or in wasting some time will still leave a profitable farm, although not so profitable as it might otherwise have been.

Every farmer will do well to compare his farm with the averages for Tompkins, Jefferson and Livingston counties (page 699). He should strive to have his farm better than the average in every point. Particular attention should be given to anything in which his farm falls below the average. A careful farmer may hope for crop yields a fifth better than the average and production per animal a half better than the average. With these conditions and a good-sized farm, he may hope for a labor income of two to five times the average after he gets his business established. In order to help the farmer in making such a study, the Department of Farm Management at Cornell University will send blanks on request to any farmer who desires to calculate his labor income. The record of the business for a year can be filled in and the blank be returned to the department. Various factors will be calculated and returned to the farmer for study, or the farmer may make these calculations for himself.

The success of a farm is primarily dependent on the factors emphasized in this bulletin. But success of an individual is primarily dependent on the relation of his income to his family expenses. The highest financial success comes when a well-balanced, successful farm is combined with reasonable economy in living.

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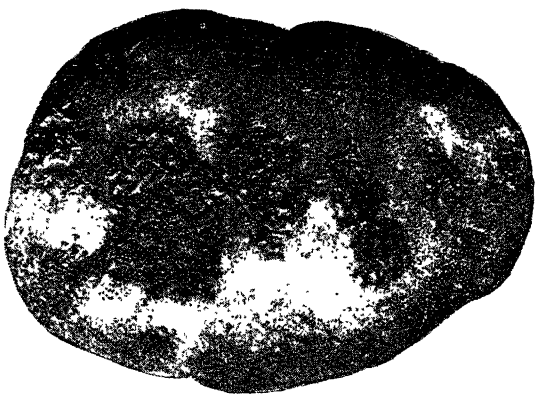
Department of Plant Pathology

POTATO SCAB AND SULFUR DISINFECTION



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CONTENTS

POTATO SCAB AND SULFUR DISINFECTION

C. D. SHERBAKOFF

(*Received for publication June 16, 1914*)

THE SCAB DISEASE OF POTATOES

The disease of potato tubers known almost universally as scab is of very wide distribution. It occurs in practically all the potato-producing countries of the world and is particularly widely distributed in the United States. The severity of the attack varies in the different countries and in different sections, but is of sufficient importance in practically all countries to have elicited the attention of plant pathologists, many of whom have made some study of the disease particularly with reference to its control.

The disease is well characterized by the name given to it. The lesions vary from small, roughened spots to deep pits and irregular channels having a rough, corky lining. They may occur in isolated areas, or may be so extensive as to involve the entire surface of the tuber.

The apparent difference between the deep and the shallow scabs appears to lie chiefly in the extent of injury and is evidently due to the conditions of development of the lesion. A condition generally spoken of as wormy scab is frequently observed. It appears to the writer that Professor Thaxter's contention is yet the one most acceptable. Thaxter (1891:83) states that it is of common occurrence, especially in "deep" scab, that a variety of insects, especially wireworms, myriapods, and mites—for which the scab spots form an attractive feeding ground—often extend the injury, but are not the original cause of it.

Badly scabbed tubers are rendered unmarketable although the culinary qualities do not seem to be diminished materially. It is not apparent that the occurrence of the disease results in a decrease in number or quantity of tubers. In the case of seed stock the occurrence of a slight amount of scab on the tubers is sufficient to cause their rejection unless disinfection is practiced. From the nature of the disease it is obvious that there are no definite statistical data at hand in regard to losses; but, considering the importance of the potato crop and the very general occurrence of the disease, the losses from it are an important item.

Thaxter (1891) proved that this disease is caused by the activities of an organism which he named *Oospora scabies*. Thaxter only tentatively placed the organism in a class of the lower fungi. It appears to belong more properly to a group of the lower plants that occupy an intermediate position between true fungi and bacteria. More recently Cunningham

(1912) proposed to transfer the organism to the class of higher bacteria, to the genus Streptothrix Cohn. On this point Morse (1912) is in full agreement with Cunningham.

But according to Gussow (1914) this generic name cannot be used for this and related organisms, because it was earlier used by Corda for a hyphomycetous fungus. According to Güssow the potato-scab organism belongs more properly to the genus Actynomyces Harz, and he has named the scab organism *Actinomyces scabies* (Thaxter) Gussow.

This organism — although it is a true parasite on the potato and is commonly carried from crop to crop on the seed tubers — may, according to Jones and Edson (1901), live saprophytically in the soil for twenty-five years or more without intervention of the host plant.

When land is not contaminated with the scab organism, the new crops can be kept free from the disease only by planting seed tubers that are absolutely free from the parasite. Tubers that do not show scab lesions are commonly selected for seed, but, since the scab organism may be present on the surface of the potato either in a minute lesion or merely adhering from chance contamination, it is becoming common practice to treat all seed stock with some one of the standard disinfectants.

When the soil becomes contaminated with the scab germ, seed treatment is of no value unless some method can be devised for eradicating the germ in the soil. In many parts of New York State the disease is held to a satisfactory minimum by a long rotation and by a proper system of fertilization. For the potato specialist who wishes to grow potatoes on a limited area and in short rotation, this practice is not applicable. It is in order to meet such conditions that many attempts have been made to find suitable soil germicides.

A very large number of substances have been tested experimentally. One of these substances, to which germicidal value is usually attached and which has been tried in a number of experiments, is sulfur. It has been the object of the investigation herein reported to determine the value of sulfur in the control of potato scab on a definite potato soil type occurring in the State.

SULFUR TREATMENT OF SOIL FOR PREVENTION OF POTATO SCAB

Work done by other investigators

The first recorded experiment on sulfur treatment of the soil for prevention of potato scab is that of Taft (1890). In his experiment flowers of sulfur, 300 pounds per acre, was tested along with various other substances for the control of scab. The result reported shows neither beneficial nor harmful effects from the sulfur treatment.

Bolley (1891), in his experiment on the effect of various substances when used for treatment of seed tubers for the prevention of scab, found that rolling the seed tubers in flowers of sulfur resulted in a crop with 48.6 per cent of scabby tubers; hence he concluded that the treatment was worthless.

Coincident with Bolley, Thaxter (1892) also performed a small field experiment "to test the effect, if any, of sulfur and of muriate of potash used as a fertilizer in the hills, upon the amount of scab produced in tubers grown on land known to be infected." He found that there was no difference between treated and untreated hills, "the tubers being very generally scabbed in all cases." In his report the quantity of sulfur used is not given.

Goff (1893), in his experiment on the use of sulfur, employed two slightly different methods of treatment. In one case the seed tubers were dipped in water and then rolled in flowers of sulfur; in the other case the seed tubers were first dropped, and then, before covering them, half a teaspoonful of flowers of sulfur was sprinkled over each tuber and the soil about. In the experimental rows half the hills were treated, while the other half were left without treatment. The result of this experiment is as follows:

	Percentage of clean tubers
Seed tubers rolled in sulfur	77.7
Untreated	64.0
Sulfur sprinkled over seed tubers	57.5
Untreated	51.3

From the above data it is evident that there was very slight, if any, decrease of scab due to either of the treatments.

Pammel (1895) treated potato seed-tubers with corrosive sublimate and sulfur. The latter was employed in "solution," 1 pound of sulfur to 7 gallons of water, the treatment lasting for two hours, one and one half hour, and one hour. The 144 hills planted with seed treated with sulfur in the above manner had 51 per cent of scabby tubers, while the 48 untreated hills had 74 per cent of scabby tubers. In regard to the experiment as a whole, the author says: "The results . . . . . are so discordant that no general conclusions can be drawn."

Halsted (1895), in his experiment performed in 1894 at Freehold, New Jersey, among other substances tried sulfur for soil treatment in connection with potato scab. Flowers of sulfur was used at the rate of 600, 300, and 150 pounds per acre, and one plat was planted with seed tubers rolled in sulfur. The apparently excellent result obtained from sulfur treatment is rendered worthless as a proof of the germicidal value of sulfur in the soil, because a mere rolling of seed tubers in sulfur, as well

as the treatments with corrosive sublimate and copper sulfate, gave equally good results.

Halsted's work on soil germicides, including sulfur, was continued for five years more, the method of sulfur treatment being varied from rolling the seed tubers in a given quantity of sulfur and then dusting the remaining sulfur over the seed tubers before they were covered, to mixing the sulfur with five times its bulk of dry soil and working the mixture into the soil with a fork. In no case was the quantity of sulfur used in a single application above 720 pounds per acre. Details of the methods employed and results obtained in these experiments can be found in Halsted's several reports (1897 a, 1897 b, 1898, 1899 a, 1900). The principal results obtained, so far as the data go, are:

1. In one out of many instances, an application of sulfur at the rate of 300 pounds per acre greatly reduced the amount of scab annually from the first year of the application to nearly the end of the experiments.

2. No reduction of scab was obtained by even the heaviest application of sulfur, 600 pounds per acre, in 1896, nor was the effect of the treatment noticeable in the following season.

3. The same treatment, which had no effect on scab in either the season when the application was made or the season following, was evidently fairly effective in the season of 1898, when the average amount of scab on the treated plats was 25.3 per cent while on the check it was 61.4 per cent.

4. The plats that received 720 pounds of sulfur showed, in 1898, the greatest and most uniform reduction of the scab — from 50.8 per cent on checks to an average of 12.5 per cent on the treated plats; but the crop on the treated plats was only a little more than half that on the untreated area (1899 a:306).

5. In 1899 a new application of sulfur at the rate of 300 pounds per acre did not show any reduction of the scab. Nor was there any noticeable reduction in any other plats treated during previous years except the three "belts" of plat 2, series 6, where the reduction of the badly scabbed tubers ranged from 59 per cent in checks to 22 per cent on the treated "belts."

From the above summary of the data presented in Halsted's reports, it is clear that his conclusion that "for practical use, 300 pounds applied to the open row are deemed sufficient" appears to have very little ground.

At the same time, it is also plain that when a sufficient quantity of sulfur is applied — in his case this quantity was about 720 pounds per acre — the scab can be reduced to a considerable extent not only during the season of application but also during the season following. When a large quantity of sulfur is applied, under certain conditions there may be also a great reduction of yield.

Brooks (1897) performed a small field experiment in order to determine the effect on potato scab of sulfur application in open furrows at the rate of 300 pounds per acre. Untreated seed and seed treated with a solution of corrosive sublimate were used. The treatment with sulfur appears to have been absolutely without any effect on the scab.

Chester (1897) reports results of an experiment in rolling seed tubers in sulfur for the prevention of scab. Tubers so treated yielded a crop of which 9.1 per cent were scabbed, as compared with 29.5 per cent of scabby tubers among those untreated.

Chester (1898) conducted another experiment on the use of sulfur for the prevention of scab. This time two field plats, seventeen by seventy feet, were used. One of the plats received an application of flowers of sulfur at the rate of 300 pounds per acre. The sulfur was spread broadcast and then harrowed in just before planting. The sulfured plat produced tubers with 12.4 per cent of scab, while the check gave 26.8 per cent of scab.

Garman (1898) performed two experiments on potato-seed treatment with sulfur flour and corrosive sublimate against scab. In one of these experiments six pots with sterile soil were used. The seed tuber for one pot was rolled in sulfur flour; for two other pots, the seed tubers were treated with corrosive sublimate; the remaining three pots were planted with untreated tubers. The new crop showed almost no scab for the corrosive sublimate treatment, while in the sulfur-treated pots there appeared nearly as much scab as in the checks. The other experiment was performed in the field. Five plats were planted with tubers treated with corrosive sublimate; three plats received an application of sulfur flour at the rate of about 150 pounds, and two other plats at the rate of 180 pounds, per acre. After every treated plat there was left an untreated plat as check. The result seems to show that the sulfur treatments did not reduce scab and somewhat increased the yield, although less than the treatment with corrosive sublimate.

In the experiments of Wheeler and Tucker (1896), large iron cans, eighteen inches in diameter and twenty-six inches in depth, were used. Each can received the same amount of the same fertilizers with the exception of lime, which was introduced in different forms for each series of three, with two cans for each kind of lime. One can of each of these series—eight all told—received an application of sulfur at the rate of 600 pounds per acre, the sulfur being thoroughly mixed with the upper 7 to 8 inches of soil. The seed tubers for all cans, before planting, were treated with standard corrosive sublimate solution. The result obtained was as follows:

1. Unlimed cans and those treated with calcium chlorid, with and without sulfur, produced tubers entirely free from scab.

2. Where air-slaked lime was employed, the sulfur treatment showed decrease of scabbed tubers from 100 per cent to 62.5 per cent, and of badly scabbed tubers from 97.2 per cent to 43.8 per cent.

3. Where calcium carbonate and wood ashes were employed, the sulfur treatment reduced the amount of badly scabbed tubers from 100 per cent only to 88.9 and 88.2 per cent, respectively.

4. In the remaining cases — that is, where calcium sulfate, oxalate, and acetate were employed — the sulfur treatment did not reduce the scab at all.

The conclusion of the authors is that the sulfur treatment, "though checking the scab somewhat, was practically useless."[1]

The above experiment was continued the next season by Wheeler and Adams (1898). In experiment A eighteen cans were employed. Each can received, before the experiment began, the same amount of barnyard manure and an application of air-slaked lime at the rate of $2\frac{1}{2}$ tons per acre. The cans were then arranged in groups of three, each group being treated with some substance such as calcium carbonate, sodium chlorid, and others. One group was left untreated. One can from each group of three was planted with untreated seed tubers, another with seed tubers treated in the standard way with corrosive sublimate solution, and the third with tubers rolled in sulfur. The quantity of sulfur used was at the rate of 300 pounds per acre. The sulfur remaining after rolling the seed tubers was dusted over the tubers before they were covered. The reported results of this experiment are as follows:

	Percentage of scabbed tubers	Percentage of badly scabbed tubers
Average without treatment.......	97	71
Average with sulfur treatment.....	93	63
Average with corrosive-sublimate treatment....................	100	69

As may be seen from the above data, the decrease in scabby potatoes due to the sulfur treatment is 4 per cent and the decrease in badly scabbed potatoes is 8 per cent.

In experiment B the same cans were used that were employed in the experiment of the previous season. The general scheme of this experiment was also the same as that of the former experiment, but this time the cans that were sulfured at the rate of 600 pounds per acre during the previous season received an additional application of sulfur at the rate of 300 pounds per acre, the method of application being the same as in experiment A. The result obtained was as follows:

[1] The largest number of tubers secured in any can was twenty, and in some cases there were only two.

Cans treated with calcium sulfate, those treated with calcium chlorid, and those untreated with calcium in any form, produced tubers entirely without scab, whether or not sulfur was applied. Summing up the results obtained with all other treatments, the data on the scab are as follows:

	Percentage of scabbed tubers	Percentage of badly scabbed tubers
Average without treatment........	91	85
Average with sulfur treatment.....	82	54

The authors concluded that "the indications are that the sulfur treatment of contaminated soils may decidedly reduce the percentage of scab if enough sulfur is employed and the moisture and other soil conditions are such that it is able to exert its maximum effect."

Wheeler, Hartwell, and Moore (1899) conducted some experiments for the purpose of ascertaining the after effect of application of sulfur on the crop following. For this purpose oats and millet were grown in galvanized pots, filled with the same soil as was used in experiment B of the previous year. The conclusion was that although a large quantity of sulfur decreases the scab, it is very injurious to cereals following unless a considerable quantity of lime is introduced into the soil.

Bernhard (1910) reports that during the year 1909 six field experiments were made. He states that in all these experiments the plats treated with sulfur differed from those untreated by a smaller percentage of scabbed potato tubers, and, although in no case did sulfur treatment entirely prevent scab, nevertheless the extent of the disease on sulfured plats was only half of that on untreated plats.

Some experiments were also performed for testing the fertilizing value of sulfur alone and in combination with some common fertilizers. In this connection two experiments are reported, the results of which are fairly uniform and show that the treatment of the soil with flowers of sulfur at the rate of 100 kilograms per one fourth hectare—that is, about 357 pounds per acre—whether alone or in combination with the same amount of 40-per-cent potash, considerably increased the yield on unfertilized as well as on fertilized land; the increase being especially great when sulfur was applied to the plats treated with nitrate of soda 66.66 per cent. The lowest increase was for sulfur on land with superphosphate and double application of potash 6.66 per cent.

From his experiments, Bernhard concludes that the sulfur evidently works in the soil as a disinfecting agent, improves the physical properties of the soil, and appears to play a much greater rôle in nourishment of plants than has formerly been ascribed to it.

Bernhard (1911 a) reports on another series of field experiments which in general were of the same type as those of the previous year. The five plats treated with sulfur invariably showed a considerable increase of yield and decrease in scab as compared with those untreated. This holds true whether or not the land was fertilized. The author claims also that the leaf-roll disease of potatoes was less prominent on sulfured plats than on others.

Bernhard (1911 b) performed another series of experiments with wooden boxes 40 centimeters square sunk in the earth. In most cases a great reduction of scab was obtained by the addition of 6 grams of sulfur to the boxes, although in some instances, when scabby seed tubers were used, the amount of scab was as high as 60 per cent. Considerable increase in yield due to the use of sulfur was obtained in this experiment. The author thinks that the action of sulfur may be due to its oxidation into sulfur dioxid and finally into sulfuric acid.

From the data on the after effect of sulfur treatment on the potato crop during 1900, Halsted (1901) found "that the untreated belts show a larger number and greater weight of tubers than the other areas, but the value of the larger crop is much less than where the sulfur had been added."

Von Feilitzen (1913), in his experiments in 1911 and 1912 with sulfur treatment of potatoes, found that in case of one variety the results were decidedly beneficial, while in most of the others the advantage was either small or negative.

Pethybridge (1912) tested the effect of different substances, including flowers of sulfur, when applied to the soil at the rate of $3\frac{1}{4}$ and $6\frac{1}{2}$ hundredweight per acre for control of the powdery scab disease (*Spongospora subterranea*). The following year he (1913) again tried sulfur applications to the soil at the rate of $6\frac{1}{2}$ hundredweight per acre. In conclusion of the latter experiment he says (1913:460) that the best treatment was that with " sulphur, where not only was the amount of disease [scab] reduced to less than one half of that in the untreated plots, but the total yield was higher than in any other case. This result confirms previous experiments carried out at Clifden, which have always shown that sulphur added to the soil increases the yield of potatoes and diminishes the attack of scab."

In all three experiments of Pethybridge no duplication of the treatment was made in any way; the checks, one or two plats, being left in only one part of the experimental field. Each plat was one square perch, or 272.25 square feet, in area.

From all the work done with treatment of seed tubers and potato soil, the following conclusions can be drawn:

1. Seed-tuber treatment with corrosive sublimate solution, liquid formaldehyde, and gas formaldehyde proved to be equally satisfactory

whenever the soil was not previously contaminated. Rolling the seed tubers in sulfur often proved to be of little or no service at all.

2. When the soil was contaminated, any of the above seed treatments proved to be of little or no use.

3. None of the substances tried as soil fungicides (kainit, corrosive sublimate, bordeaux, cuprum, and the like), except sulfur, proved to be effective for checking scab.

4. Sulfur (flour and flowers commonly used), whenever applied in sufficient quantity (720 to 900 pounds per acre), reduced scab to a more or less considerable extent; but under certain conditions during the year of application or the following season, it caused a decided decrease in yield. Smaller amounts (300 to 600 pounds per acre) apparently were effective only under certain favorable conditions of soil and weather.

5. From the data existing in the literature on the subject, it seems that the reaction of the soil greatly influences the development of scab, the acidity acting as a checking factor in proportion to its degree.

6. It is also very manifest that fertilizers increasing alkalinity of the soil, such as lime, greatly favor scab development; while acid phosphate, sulfate of ammonia, and the like, at least do not increase scab injuries.

Experimental work at this station

Principles of field experiments

According to Mercer and Hall (1911), "an error is always attached to the result no matter how seemingly uniform is the land and careful the management of the experiment." Moreover, the error may be so great as to render an entire experiment worthless. The latter case is more common than is usually suspected.

The environment and the individuality of every plant are of extreme importance not only in the resultant yield but also in the freedom of the plants from diseases. No individual plant is exactly like another, and no environmental conditions of any plant can be exactly like those of its neighbors. The former and the latter always vary, and often the variation is sufficient to mask the effect of a special treatment that is tested by an experiment. This is as true in the field experimentation of a plant pathologist as it is in the case of a plant-breeder or a soil technologist, unless it can be shown that susceptibility of plants to diseases, and the extent of the injuries caused by the latter, do not vary with plants and environment.

It is improbable that the experimental error due to the two factors above indicated can ever be entirely eliminated, and indeed an entire elimination of it is not important. What is important and what can be done is to diminish the error to a sufficiently low and known degree. Then

it will not interfere with practical conclusions and with a proper interpretation of the experimental results.

In any experiment the aim is to find the effect of the tested treatment, the actual effect for any treatment being evidently equal to the result of the treatment minus the result of no treatment of the same object. Since it is impossible to have the same object treated and untreated simultaneously, the only way to solve the above question is to find a substitute for one of its members. The substitute for the untreated object is known as the check, and it is evident that the more the check is like the treated object minus treatment, the nearer we are to the truth. Hence proper selection of the check is the important point in any experiment. For any field experiment this check must be selected with regard to the soil as well as with regard to the plants.

In respect to the soil checks, Lyon (1912) states that they can be employed with advantage only when they are represented by every other, or at least every third, plat. The checks as they have been commonly used — a few plats or a strip of land left untreated — represent conditions of soil far from the same as those on the treated plats, and therefore mean very little or nothing at all. But even when every other plat or every third plat is left as a check, the check may often differ greatly in soil from the treated plat because of a sudden change in soil. Therefore duplication of the same treatment is absolutely indispensable. Lyon states that the error diminishes by increasing the number of similarly treated plats four or five times, but that there is not much gain in accuracy by a still greater repetition.

In regard to variability in the plant, it has been found that although individual plants do vary considerably, they nevertheless are, on an average, constant enough when a large number of them are considered. Lyon (1912) says that at least one hundred plants must be used in every case. This number apparently is given for cereals; other plants would perhaps differ considerably in this respect.

As the number of plants that could normally be grown on a plat is limited by its size, and as the probable variation in soil is evidently greater when plats are smaller, the size of the plats must also be considered in connection with experimental error. It has been generally accepted that, the larger the plats, the smaller is the expected experimental error. But, as has been shown, this is true only to a certain extent. Thus Mercer and Hall (1911), in their work with mangels and wheat, found that there is no special advantage in using plats larger than one fiftieth acre in size, while Wood and Stratton (1910) found that plats of one eightieth acre in size gave just as small probable error as did the larger plats up to one fourth of an acre in size. Obviously the size of the plat depends

to a considerable extent on the soil conditions, the plant, and the nature of the treatment with which we are dealing.

Thus in a field experiment the following points must be taken as basis for layout of the field:

1. Checks to be left on every other, or at least every third, plat.
2. The same treatment to be repeated four to five times.
3. Each plat to contain at least one hundred plants.
4. The size of the plats to be not less than one eightieth of an acre.

Of course other precautions must be observed, such as to work on as uniform land as possible; to use plants of a pure line; to give the same cultivation and care; and the like.

After observing all means of diminishing the error of field experimentations, there will still be left many other factors that also affect the result and that cannot be controlled and calculated. The error due to these factors can be considered as a casual one, and as such can be determined by calculation of the so-called probable error[2]; this is a measure of the reliability of the experimental results, and means that the odds are equal that the true result lies somewhere within the actually obtained data ± probable error.

It is assumed by Wood and Stratton (1910) that desirable precision is that of at least 3.8 times the probable error, corresponding to odds of thirty to one that the result obtained is due to the treatment and not to a chance variation.

Plan for and management of the field experiments

In laying out field experiments and in representing the data obtained from these experiments, the general principles enumerated above were observed in so far as it was practicable under the conditions of the work. In the plan of these experimental fields especial attention was paid to the checks and to repetition of treatments. The treatments that were of primary importance were repeated four and five times, while those treatments that were, from the point of view of the main problem, of secondary importance were repeated at least twice. In one experimental field where sulfur alone was tested, the same treatment was repeated six times. Checks were left on either every third plat or every other plat. The size of plats varied from three eightieths to one eightieth of an acre.

In the tables in which the data are represented the probable error is given wherever it seems to be of any value.

In all the experiments the potatoes were planted either by hand or with a planter, spacing three feet between the rows and eighteen inches be-

[2] Probable error as worked out is equal to $\pm\ 0.6745\sqrt{\frac{\Sigma d^2}{n\ (n-1)}}$

tween the plants in the rows. No attempt was made to select clean tubers for seed, nor were they treated with any kind of antiseptic.

During the season of growth all experimental fields were uniformly kept in a proper state of cultivation and were sprayed with bordeaux mixture plus paris green when necessary, so as to keep the crop free from the early and late blights and the potato beetle.

Frequent observations of the growth of the plants on the experimental fields were made; but in no case were any marked differences between the treated and the untreated plats observed, except in the plats that were treated with commercial fertilizer. Those plats always showed a much better growth of the plants when compared with the plants on all other plats.

With the exception of field No. 3, all fields were planted with potatoes of a variety known as "Blue Sprouts No. 9"; field No. 3 was planted with a red potato of the variety Early Manistee.

At digging time the potatoes were sorted in the field into the following classes: clean, entirely free from scab; scabby, the tubers with one to many scab spots; and culls, so badly scabbed as to be unmarketable.

Experiments of 1911

The first field experiments on the value of sulfur treatment of soil for the prevention of potato scab were made by C. N. Jensen, with the author's assistance, in 1911 at Atlanta, New York, on a field which is here referred to as field No. 1.

Because of the absence of a proper system of checks, and also because there was no true duplication of the same treatments, the results obtained from this field are of small value when considered by themselves. But since in their main features they are confirmed by the later work, it perhaps will be of some interest to give here at least a brief account of the results obtained from this field in 1911. These are as follows:

1. In all cases when 900 pounds of sulfur per acre were applied there were very few scabby and almost no cull tubers; on an average the reduction of the total scab was about twenty per cent (19.5 per cent) when compared with the checks, the latter having on an average 6.7 per cent of cull and 22 per cent of scabby tubers. The same application of sulfur was nearly as effective when a small quantity of lime (500 pounds per acre) was added to the sulfured plat.

2. The application of 300 and 600 pounds of sulfur per acre reduced scab only slightly. The reduction was 10.3 and 11.5 per cent in total scab, respectively, when compared with the checks.

3. There was no indication of any reduction of the yield of the crop by sulfur treatment, even when the larger quantity was employed.

Experiments of 1912

Experimental field No. 1.—Notwithstanding the faulty layout of this field, it seemed that the work could be continued here with some profit for one year more, with the object of determining the after effect of sulfur treatment on the same crop, potatoes.

Accordingly the field was planted to potatoes in the spring of 1912. No new application of sulfur was made on the main part of this field, but a commercial fertilizer with potash and phosphate in equal proportion was applied in four strips so as to fertilize one half of each original plat. The data obtained from this part of the field are summed up in Table 1, in

TABLE 1. SUMMARY OF THE DATA FROM FIELD NO. 1, TREATED WITH SULFUR IN 1911

(The plats were approximately one tenth acre in size in 1911. Half of each plat was fertilized with a commercial fertilizer in 1912 — potash 10, phosphoric acid 10, applied at the rate of 650 pounds per acre)

Plats	Treatment	Yield (pounds pe. acre)	Percentage of scabby tubers	Percentage of culls
1911				
3, 5, 9, 13	Checks	8,620	32.2	7.7
1, 6, 10, 14	Sulfur, 300 pounds per acre	8,390	12.0	2.0
2, 7, 11, 15	Sulfur, 600 pounds per acre	9,047	11.7	1.4
4, 8, 12, 16	Sulfur, 900 pounds per acre	9,600	8.2	0.0
1912, fertilized part				
3, 5, 9, 13	Checks in 1911	11,955	50.9	14.3
1, 6, 10, 14	Sulfur, 300 pounds per acre in 1911	11,685	34.3	9.0
2, 7, 11, 15	Sulfur, 600 pounds per acre in 1911	10,669	15.3	4.3
4, 8, 12, 16	Sulfur, 900 pounds per acre in 1911	9,088	2.7	0.7
1912, unfertilized part				
3, 5, 9, 13	Checks	9,567	16.0	5.0
1, 6, 10, 14	Sulfur, 300 pounds per acre in 1911	7,623	21.2	3.4
2, 7, 11, 15	Sulfur, 600 pounds per acre in 1911	8,486	3.6	0.1
4, 8, 12, 16	Sulfur, 900 pounds per acre in 1911	8,569	3.0	0.35

which is given also a similar summary of the data for the same plats for 1911. The quantity of cull, scabby, and clean tubers was determined by sorting the two middle rows of each plat. The table shows that the amount of scab was considerably reduced by application of sulfur at the

FIG. 105

Part A		Part B	
1 Buffer		1 Buffer	
2 Check		2 Check	
3 Sulfur	450 lbs. per acre	3 Sulfur	550 lbs. per acre
4 Sulfur	900 " " "	4 Sulfur	900 " " "
5 Check		5 Check	
6 Lime	350 " " "	6 Lime	400 " " "
7 { Lime Sulfur	350 " " " 450 " " "	7 { Lime Sulfur	400 " " " 450 " " "
8 Check		8 Check	
9 { Lime Sulfur	350 " " " 900 " " "	9 { Lime Sulfur	400 " " " 900 " " "
10 Commercial fertilizer	1000 " " "	10 Commercial fertilizer	900 " " "
11 Check		11 Check	
12 { Commercial fertilizer Sulfur	1000 " " " 450 " " "	12 { Commercial fertilizer Sulfur	900 " " " 450 " " "
13 Sulfur	450 " " "	13 { Commercial fertilizer Sulfur	900 " " " 900 " " "
14 Check		14 Check	
15 Sulfur	900 " " "	15 Sulfur	450 " " "
16 { Lime Sulfur	350 " " " 450 " " "	16 Sulfur	900 " " "
17 Check		17 Check	
18 { Lime Sulfur	350 " " " 900 " " "	18 Lime	400 " " "
19 Sulfur	450 " " "	19 { Lime Sulfur	400 " " " 450 " " "
20 Check		20 Check	
21 { Commercial fertilizer Sulfur	1000 " " " 900 " " "	21 { Lime Sulfur	400 " " " 900 " " "
22 Check		22 Commercial fertilizer	900 " " "

	Part A			Part B	
23	Commercial fertilizer	1000 lbs. per acre	23	Check	
24	Commercial fertilizer Sulfur	1000 " " " 450 " " "	24	Commercial fertilizer Sulfur	900 lbs. per acre 450 " " "
25	Check		25	Commercial fertilizer Sulfur	900 " " " 900 " " "
26	Sulfur	450 " " "	26	Check	
27	Sulfur	900 " " "	27	Sulfur	900 " " "
28	Check		28	Lime Sulfur	400 " " " 450 " " "
29	Lime	350 " " "	29	Check	
30	Lime Sulfur	350 " " " 450 " " "	30	Lime Sulfur	400 " " " 900 " " "
31	Check		31	Check	
32	Lime Sulfur	350 " " " 900 " " "	32	Sulfur	450 " " "
33	Commercial fertilizer Sulfur	1000 " " " 900 " " "	33	Sulfur	900 " " "
34	Check		34	Check	
35	Sulfur	450 " " "	35	Commercial fertilizer Sulfur	900 " " " 450 " " "
36	Sulfur	900 " " "	36	Commercial fertilizer Sulfur	900 " " " 900 " " "
37	Check		37	Check	
38	Buffer		38	Buffer	

FIG. 105.— *Field No. 2. General plan of the experiments of 1912 and 1913. Each plat represents 3 rows of potatoes 3 feet apart and 182½ feet long, making 3/80 acre each. The lines represent the buffer rows that were left between each plat.*

Part A was treated in 1912. In 1913 it received a general application of commercial fertilizer only, at the rate of 900 pounds per acre. Part B was treated in 1913. In 1912 it received commercial fertilizer at the rate of 1000 pounds per acre and lime at the rate of 350 pounds per acre.

rate of 600 to 900 pounds per acre. It shows also, at least in the case of the fertilized halves, that the yield was decreased by the previous year's application of sulfur, the decrease being largest where the application was heaviest.

Experimental field No. 2.—For the sake of more definite results than could be obtained from field No. 1, it was deemed necessary to conduct the experiments on a more suitable field. Such a field was found near by, and this is known hereafter as field No. 2. This field was under potatoes in 1911, and during that year it produced a comparatively uniform yield with a uniform and considerable amount of scab. The field is level and the soil is of a gravelly loam type closely related to the Dunkirk series, a soil commonly used in the State for potato culture. The layout of this field and the treatment are shown in Fig. 105. It may be seen that the entire field was divided into two equal parts with a strip of land nine feet in width between them. Each part was subdivided into thirty-eight plats, the size of each plat being 182½ by 12 feet, or very close to one twentieth of an acre.

During the season of 1912 only the east part of the field, designated as part A, was used for testing the value of sulfur treatment of the soil for scab. Part B was not treated with sulfur but was used for the purpose of finding the natural variability of the soil in yield and in scab, and also for getting the soil in condition for a still more uniform and thorough contamination with scab for the experiments of the succeeding year. Part B received a uniform application of commercial fertilizer (potash and phosphate 8-10) at the rate of 1000 pounds per acre plus air-slaked lime at the rate of 350 pounds per acre.

In determining treatments and the quantities in which to apply the substances used, it was intended to limit the work to as few different materials as possible so that these few materials could be tested more thoroughly. At the same time such quantities of sulfur were selected that, on the one hand, the smallest quantity might be expected to give a more or less noticeable decrease in scab, while the largest quantity, so far as could be judged, would not be great enough to cause any serious injury to the crop. A small application of lime, alone and with sulfur, was also tested, in the belief that a combination of lime and sulfur might prove to be more beneficial to the crop than sulfur alone. A heavy application of commercial fertilizer was made because of the fact that a heavy application would result in a more pronounced difference, and therefore would give a more definite idea as to the fertilizing value, if any, of sulfur alone and in combination with the fertilizer. This particular kind of fertilizer was chosen because it is commonly used for potatoes by local farmers.

The field was planted, cultivated, and sprayed in the same way as was field No. 1. The fertilizer, lime, and sulfur were applied with a drill, instead of by hand as was done on field No. 1.

The data on scab control from field No. 2, part A, are presented in Table 2. The data were obtained by sorting all the tubers from the three rows of each plat, the fourth row between the plats being left as a buffer row. The tubers were sorted into clean, scabby, cull, and rough-skin tubers. The last named were tubers with a more or less deeply cracked surface. The injury as a rule was not of such a kind as to reduce the value of the crop in any respect. In a few exceptional cases the cracking of the surface of the tubers was sufficient to be objectionable, at least for table use.

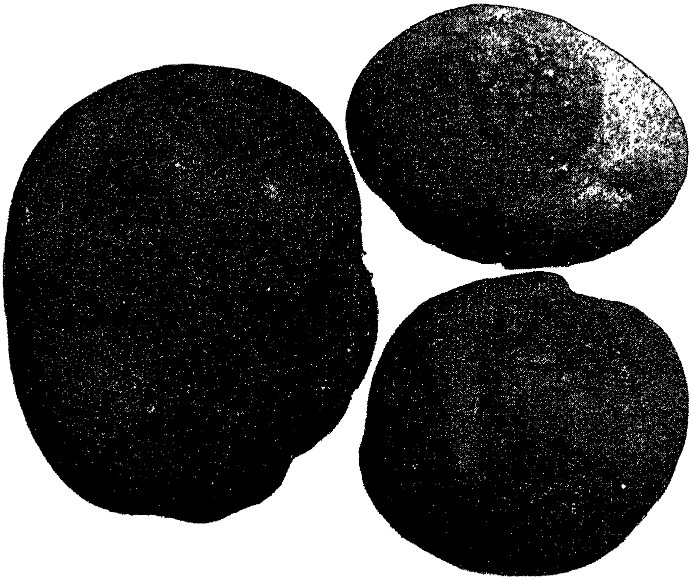

FIG. 106.—*Rough-skin tubers found where excess of sulfur was used in connection with commercial fertilizer*

Such a specimen is shown in Fig. 106. The rough skin was observed exclusively on the plats treated with sulfur, and the greatest amount occurred where sulfur and commercial fertilizer were applied together. No such injury was observed during either the preceding or the succeeding season. This season differed from the others in being comparatively very rainy.

The tubers were also sorted, according to their size, into firsts and seconds; but, since these data did not show anything for any of the treatments, they are omitted from the tables.

In Table 2, parallel with the actual data, are given also the data for the calculated checks, with the difference in percentage between the treated

TABLE 2. DATA FOR 1912 FROM FIELD NO. 2, PART A, TREATED IN 1912. ACTUAL

Treatment (pounds per acre)	Plat	Yield		Clean			
		Pounds per plat	Calculated check percentage	Pounds per plat	Percentage	Calculated check percentage	Difference percentage
Check	2	375.00	...	202.0	53.87	...	...
Sulfur 450	3	400.50	106.40	273.5	68.29	56.73	11.50
Sulfur 900	4	386.50	102.26	313.0	80.98	59.59	21.39
Check	5	379.50	...	237.0	62.45	...	...
Lime 350	6	398.00	107.01	229.5	57.66	62.27	—4.61
Lime 350 } Sulfur 450 }	7	382.75	104.93	260.5	68.06	62.09	5.97
Check	8	357.00	...	221.0	61.90	...	...
Lime 350 } Sulfur 900 }	9	369.00	103.60	309.0	83.74	64.51	19.23
Commercial fertilizer 1000	10	507.00	142.68	200.5	39.55	67.12	—27.57
Check	11	354.25	...	247.0	69.72	...	...
Commercial fertilizer 1000 } Sulfur 450 }	12	465.50	122.23	273.5	58.75	65.26	—6.51
Sulfur 450	13	405.50	99.67	336.5	82.98	60.79	22.19
Check	14	433.25	...	244.0	56.32	...	...
Sulfur 900	15	415.00	104.48	341.0	82.17	53.57	28.60
Lime 350 } Sulfur 450 }	16	447.25	123.94	351.0	78.48	50.82	27.66
Check	17	324.50	...	156.0	48.07	...	...
Lime 350 } Sulfur 900 }	18	405.50	115.51	337.0	83.11	47.30	35.81
Sulfur 450	19	390.00	103.28	288.5	73.97	46.53	27.44
Check	20	404.25	...	185.0	45.76	...	...
Commercial fertilizer 1000 } Sulfur 900 }	21	513.25	119.11	379.0	73.84	49.69	24.15
Check	22	457.50	...	245.25	53.61	...	...
Commercial fertilizer 1000	23	595.50	137.07	305.5	51.30	57.03	—5.73
Commercial fertilizer 1000 } Sulfur 450 }	24	539.75	131.52	310.5	57.53	60.46	—2.93
Check	25	386.75	...	247.0	63.87	...	...
Sulfur 450	26	386.75	100.59	266.5	68.91	65.83	3.08
Sulfur 900	27	398.50	104.24	334.0	83.81	67.78	16.04
Check	28	380.00	...	265.0	69.74	...	...
Lime 350	29	393.00	107.97	233.0	59.29	70.59	—11.30
Lime 350 } Sulfur 450 }	30	411.00	110.93	336.0	81.75	71.44	10.31
Check	31	399.75	...	289.0	72.29	...	...
Lime 350 } Sulfur 900 }	32	368.25	89.26	317.0	86.08	72.09	13.99
Commercial fertilizer 1000 } Sulfur 900 }	33	502.25	118.03	413.0	82.23	71.89	10.34
Check	34	438.00	...	314.0	71.69	...	...
Sulfur 450	35	469.25	102.66	373.0	79.49	71.41	8.08
Sulfur 900	36	449.00	94.28	381.0	84.86	71.12	13.74
Check	37	495.50	...	351.0	70.84	...	...

plats and the checks. The effect of the treatments on the scab and the yield is shown in Table 3, in which appears the increase or decrease in scab and yield of the treated plats over the corresponding checks. In this table are given also the averages, with their probable errors, for the same kinds of treatment.

From Table 3, it appears (1) that a noticeable decrease of scab was obtained by 450 pounds of sulfur per acre in all cases, except when sulfur was in combination with commercial fertilizer; (2) that the decrease in scab was twice as great when 900 pounds of sulfur was applied, the scab being reduced by this treatment just as much whether sulfur was applied

YIELD AND AMOUNT OF SCAB FOR THE VARIOUS PLATS AND THE CALCULATED CHECKS

Scabby: Pounds per plat	Scabby: Percentage	Scabby: Calculated check percentage	Scabby: Difference percentage	Culls: Pounds per plat	Culls: Percentage	Culls: Calculated check percentage	Culls: Difference percentage	Rough skin: Pounds per plat	Rough skin: Percentage	Rough skin: Calculated check percentage	Rough skin: Difference percentage
141.0	37.60	...	...	32.0	8.53	...	...	...	...	...	...
108.0	26.97	35.95	−8.98	13.5	3.37	7.32	−3.95	5.5	1.37	...	1.37
54.0	13.97	34.31	−20.34	1.0	0.26	6.10	−5.84	18.5	4.79	...	4.79
124.0	32.67		...	18.5	4.88	...	...	...	...	...	...
141.0	35.43	31.86	3.57	27.5	6.91	5.87	1.04	...	...	...	...
108.0	28.22	31.05	−2.83	13.5	3.53	6.86	−3.33	0.75	0.19		0.19
108.0	30.25	...	...	28.0	7.85	...	...	...	...	...	...
50.0	13.55	29.20	−15.65	5.25	1.42	6.29	−4.87	4.75	1.29	...	1.29
261.5	51.58	28.15	23.43	45.0	8.87	4.73	4.14		...	...	...
96.0	27.10	...	...	11.25	3.18	...	...	...	...	...	...
127.0	27.28	31.53	−4.25	33.5	7.20	3.01	4.16	31.5	6.77	0.17	6.60
63.0	15.54	35.96	−20.42	5.0	1.23	2.91	−1.68	1.0	0.25	0.34	−0.09
175.0	40.39	...	...	12.0	2.77	...		2.25	0.52		...
67.5	16.26	42.95	−26.69	6.0	1.45	3.08	−1.63	0.5	0.12	0.40	−0.28
90.0	20.12	45.51	−25.39	5.25	1.17	3.39	−2.22	1.0	0.23	0.28	−0.05
156.0	48.07	...	...	12.0	3.70	...	...	0.5	0.16	...	...
63.0	15.54	49.20	−33.66	3.0	0.74	3.40	−2.66	2.5	0.61	0.10	0.52
87.5	22.44	50.33	−27.89	10.0	2.56	3.09	−0.53	4.0	1.03	0.05	0.98
208.0	51.46	...	...	11.25	2.78	...	...	...	...	...	...
86.0	16.76	47.80	−31.04	5.25	1.02	2.40	−1.38	43.0	8.38	0.11	8.27
202.0	44.15	...	...	9.25	2.02	...	...	1.0	0.22	...	...
260.0	43.66	40.61	3.02	30.0	5.04	2.14	2.90	...	...	0.19	−0.19
194.0	35.94	37.12	−1.18	14.75	2.73	2.27	0.46	20.5	3.80	0.15	3.65
130.0	33.61	...	...	9.25	2.39	...	...	0.5	0.13	...	...
109.0	28.18	31.71	−3.53	3.5	0.91	2.38	−1.47	7.75	2.00	0.08	1.92
34.0	8.53	29.80	−21.27	0.5	0.13	2.38	−2.26	30.0	7.53	0.04	7.49
106.0	27.89	...	...	9.0	2.37	...	...	...	...	...	...
146.0	37.15	27.10	10.05	14.0	3.56	2.23	1.33	...	...	0.08	−0.08
66.0	16.06	26.31	−10.25	5.5	1.34	2.08	−0.74	3.5	0.85	0.17	0.68
102.0	25.52	...	...	7.75	1.94	...	...	1.0	0.25	...	...
17.0	4.62	25.54	−20.92	3.25	0.88	2.21	−1.33	31.0	8.42	0.16	8.26
44.0	8.76	25.56	−16.80	5.25	1.05	2.48	−1.43	40.0	7.96	0.07	7.89
112.0	25.57	...	...	12.0	2.74	...	...	...	...	...	...
80.0	17.05	25.45	−8.40	10.0	2.13	3.14	−1.01	6.25	1.33	...	1.33
29.0	6.46	25.34	−18.88	4.0	0.89	3.54	−2.65	35.0	7.79	...	7.79
125.0	25.23	...	...	19.5	3.93	...	...	...	...	...	...

alone or in combination with lime or with commercial fertilizer; (3) that there was very little, if any, increase in the yield when sulfur alone was applied; (4) that when sulfur was used in combination with commercial fertilizer, the decrease in yield as compared with commercial fertilizer alone was considerable, and the greater decrease was when the larger quantity of sulfur was applied.

On part B of field No. 2, every ninth row was sorted at the time of digging and every grade was recorded. These data are given in Table 4, which shows that the yield varied considerably, yet without sudden jumps except in row No. 15, the yield of which was much lower than that of any

of the next measured rows. This, as it seems, speaks much in favor of using the two nearest checks instead of the average of all checks as a basis of comparison. The table shows also that this part of the field was heavily and uniformly infected with the scab, the amount of scab also not representing sudden jumps from any one of the measured rows to another.

Summary of the work of 1912.—So far as the above data go, the following can be stated: (1) Scab was considerably reduced by an application of sulfur at the rate of 450 to 900 pounds per acre in all cases except when

TABLE 3. PERCENTAGE OF INCREASE (+) OR OF DECREASE (—) IN THE VARIOUS CLASSES OF POTATOES AND IN YIELD FOR FIELD NO. 2, PART A, AS COMPARED WITH THE CORRESPONDING CHECKS. TREATMENT AND DATA FOR 1912 *

Treatment (pounds per acre)	Plat	Clean (percentage)	Scabby (percentage)	Culls (percentage)	Rough skin (percentage)	Yield (percentage)
Sulfur 450	3	+11 56	— 8.98	—3 95	+1 37	+ 6 40
	13	+22 19	—20.42	—1 68	—0.09	— 0 33
	19	+27 44	—27 89	—0 53	+0.98	+ 3 28
	26	+ 3 08	— 3 53	—1.47	+1 92	+ 0 59
	35	+ 8 08	— 8 40	—1 01	+1 33	+ 2 66
Average		+14 47±2 96	—13 84±3.02	—1 73±0 40	+1 10±0.23	+ 2 52±0.79
Lime 350, Sulfur 450	7	+ 5 97	— 2 83	—3 33	+0 19	+ 4 93
	16	+27 66	—25 39	—2 22	—0 05	+23 94
	30	+10 31	—10 25	—0 74	+0 68	+10 93
Average		+14 65±4.47	—12 82±4 48	—2 10±0.51	+0 27±0.14	+13.27±3.78
Commercial fertilizer 1000, Sulfur 450	12	— 6 51	— 4 25	+4.16	+6.60	+22.23
	24	— 2.93	— 1 18	+0.46	+3 64	+31 52
Average		— 4.72±1.21	— 2 72±1.04	+2 31±1.25	+5 12±1.00	+26 87±3.13
Sulfur 900	4	+21.39	—20 34	—5 84	+4 79	+ 2.26
	15	+28.60	—26.69	—1 63	—0.28	+ 4 48
	27	+16 04	—21 27	—2 26	+7 49	+ 4 24
	36	+13 74	—18 88	—2 65	+7 79	— 5 72
Average		+19 94±2.23	—21 79±1.15	—3.10±0.63	+4 95±1.26	+ 1.32±1.62
Lime 350, Sulfur 900	9	+19.23	—15 65	—4 87	+1 29	+ 3 60
	18	+35.81	—33.66	—2 66	+0 52	+15 51
	32	+13.99	—20.92	—1.33	+8.26	—10.74
Average		+23 01±4.44	—23.41±3.61	—2 95±0.69	+3 36±1.66	+ 2.79±5.08
Commercial fertilizer 1000, Sulfur 900	21	+24.15	—31.04	—1 38	+8.27	+19.11
	33	+10.34	—16.80	—1.43	+7 88	+18.03
Average		+17.25±4.66	—23 92±4.80	—1.41±0.02	+8 08±0 13	+18 57±0.36
Lime 350	6	— 4.61	+ 3 57	+1.04	0 00	+ 7 01
	29	—11.30	+10.05	+1.33	—0 08	+ 7 97
Average		— 7.95±2.26	+ 6 81±2.19	+1 18±0.10	—0.04±0.03	+ 7 49±0.32
Commercial fertilizer 1000	10	—27.57	+23.43	+4.14	0.00	+42.68
	23	— 5.73	+ 3 02	+2.90	—0.19	+37 07
Average		—16 65±7.37	+13 22±6.88	+3.52±0.42	—0.09±0.06	+39.88±1.89

* All probable errors throughout this work were calculated by formula $\pm 0.6745\sqrt{\frac{\Sigma d^2}{n(n-1)}}$

TABLE 4. A CLASSIFICATION OF THE YIELD OF POTATOES FROM FIELD NO. 2, PART B, FOR THE YEAR 1912, SHOWING A GENERAL INFESTATION OF SCAB FOR THE SUCCEEDING YEAR

Row	Yield (pounds per acre)	Seconds (percentage)	Scabby (percentage)	Culls (percentage)
7	10,550	6.7	52.5	7.6
16	9,600	5.0	58.3	10.0
25	11,300	4.4	55.9	14 8
34	11,680	3.4	60.9	17 8
43	11,120	4.8	78.8	20.8
52	15,300	3.0	65.6	14 1
61	15,960	3.7	72.3	21.2
70	13,550	3.1	73.1	28.9
79	13,780	3.6	63.7	15.0
88	13,680	3.5	62.4	8.1
97	13,320	2.7	63.0	10 2
106	12,920	3.1	61.2	7.1
115	11,480	3.8	64.7	13.2
124	13,420	2 8	56.2	5.9
133	11,960	6.9	58.1	14.7
142	12,340	4 6	52.4	13.5
151	13,840	0.0	47.9	13.8

450 pounds of sulfur was applied together with the commercial fertilizer, in which case practically no decrease of scab was obtained. The greatest and most uniform decrease was obtained when 900 pounds of sulfur was applied. (2) In all cases the yield either was not affected or was very slightly increased with sulfur treatment, except when sulfur was applied together with commercial fertilizer, in which case there was a noticeable decrease as compared with commercial fertilizer alone. (3) Both the scab and the yield were decreased by sulfur treatment of the preceding season (Table 1), the decrease of scab being much greater than that of yield.

Experiments of 1913, field No. 2

The experimental work on this field during the season of 1913 was performed as shown in Fig. 105. It is seen that the work on part B in 1913 was nearly an exact duplication of that on part A in 1912, with very few and unimportant deviations as follows: (1) a somewhat more uniform distribution of the number of plats treated in the same way; (2) lime was applied in quantities of 400 pounds instead of 350 pounds per acre; and (3) commercial fertilizer was applied at the rate of 900 pounds instead of 1000 pounds per acre, and contained some nitrogen 2-8-10. Moreover, this spring the potatoes were planted by hand, with the field marked

TABLE 5. DATA FOR 1913 FROM FIELD NO. 2, PART A, TREATED IN 1912. ACTUAL

Treatment (pounds per acre)	Plat	Yield: Pounds per plat	Yield: Calculated check (percentage)	Clean: Pounds per plat	Clean: Percentage	Clean: Calculated check (percentage)	Clean: Difference (percentage)
Check	2	132.50	....	60	45.28	....	....
Sulfur 450	3	124 00	92.40	77	62.10	44.19	17.91
Sulfur 900	4	103.00	75 74	72	69.90	43.11	26.79
Check	5	138.00	....	58	42.03	....	....
Lime 350	6	140.00	102.53	38	27.14	44.25	—17.11
Lime 350, Sulfur 450	7	134.00	99.22	58	43.28	46.47	—3.19
Check	8	133.50	....	65	48.69	....	....
Lime 350, Sulfur 900	9	115.00	89 78	71	61.74	46.58	15.16
Commercial fertilizer 1000	10	137.50	111 69	45	32.73	44.48	—11.75
Check	11	118.00	....	50	42.37	....	....
Commercial fertilizer 1000, Sulfur 450	12	105.00	87.28	58	55.24	43.72	11 52
Sulfur 450	13	109.00	88 98	80	73 39	45.06	28.33
Check	14	125.00	....	58	46 40	....	....
Sulfur 900	15	82.50	65.79	56	67.88	44.64	23.24
Lime 350, Sulfur 450	16	123.00	97.74	64	52.04	42.88	9.16
Check	17	126.50	....	52	41.11	....	....
Lime 350, Sulfur 900	18	113.50	89.06	78	68.72	41.28	27.44
Sulfur 450	19	121.00	94.17	70	57.85	41.45	16.40
Check	20	129.75	....	54	41.62	....	....
Commercial fertilizer 1000, Sulfur 900	21	111.50	82.01	74	66.37	43 66	22.71
Check	22	142.25	....	65	45.70	....	....
Commercial fertilizer 1000	23	150.00	110.01	40	26.67	47.27	—20.60
Commercial fertilizer 1000, Sulfur 450	24	126.00	96.44	66	52.38	48.84	3 54
Check	25	125.00	....	63	50.40	....	....
Sulfur 450	26	105 00	81.59	69	65.71	50.27	15.44
Sulfur 900	27	113.25	85.50	94	83.00	50.14	32.86
Check	28	136.00	....	68	50.00	....	....
Lime 350	29	141.25	102.95	48	33.98	53.48	—19.50
Lime 350, Sulfur 450	30	144.00	104.35	61	42.36	56.96	—14.60
Check	31	139.00	....	84	60.43	....	....
Lime 350, Sulfur 900	32	144.00	98.06	112	77.78	59.57	18.21
Commercial fertilizer 1000, Sulfur 900	33	142.50	92.14	110	77.19	58.71	18.48
Check	34	162.50	....	94	57.85	....	....
Sulfur 450	35	164.25	107.78	114	69.41	67.35	2.06
Sulfur 900	36	169.75	119.41	136	80.12	76.85	3.27
Check	37	132 00	....	114	86.36	....	....

YIELD AND AMOUNT OF SCAB FOR THE VARIOUS PLATS AND THE CALCULATED CHECKS

Scabby				Culls			
Pounds per plat	Percentage	Calculated check (percentage)	Difference (percentage)	Pounds per plat	Percentage	Calculated check (percentage)	Difference (percentage)
69	52.08	....	....	3.5	2.64	....	....
47	37.90	53.56	—15.66	....	....	2.25	—2.25
31	30.10	55.04	—24.94	....	....	1.85	—1.85
78	56.52	....	....	2.0	1.45	....	....
100	71.43	53.41	18.02	2.0	1.43	2.34	—0.91
75	55.97	50.30	5.67	1.0	0.75	3.23	—2.48
63	47.19	....	....	5.5	4.12	....	....
44	38.26	50.10	—11.84	....	....	3.32	—3.32
91	66.18	53.01	13.17	1.5	1.09	2.51	—1.42
66	55.93	....	....	2.0	1.70	....	....
47	44.76	54.88	—10.12	....	....	1.40	—1.40
29	26.61	53.84	—27.23	....	....	1.10	—1.10
66	52.80	....	....	1.0	0.80	....	....
26	31.52	54.17	—22.65	0.5	0.60	1.19	—0.59
58	47.15	55.54	—8.39	1.0	0.81	1.58	—0.77
72	56.92	....	....	2.5	1.97	....	....
35	30.84	56.70	—25.86	0.5	0.44	2.02	—1.58
50	41.32	56.48	—15.16	1.0	0.83	2.07	—1.24
73	56.26	....	....	2.75	2.12	....	....
37	33.18	54.49	—21.31	0.5	0.45	1.85	—1.40
75	52.72	....	....	2.25	1.58	....	....
107	71.33	51.14	20.19	3.0	2.00	1.59	0.41
59	46.83	49.57	—2.74	1.0	0.79	1.59	—0.80
60	48.00	....	....	2.0	1.60	....	....
34.5	32.86	47.93	—15.07	1.5	1.43	1.80	—0.37
19	16.78	47.86	—31.08	0.25	0.22	2.00	—1.78
65	47.79	....	....	3.0	2.21	....	....
87	61.59	44.81	16.78	6.25	4.43	1.71	2.72
80	55.56	41.83	13.73	3.0	2.08	1.21	0.87
54	38.85	....	....	1.0	0.72	....	....
31	21.53	39.23	—17.70	1.0	0.69	1.20	—0.51
32	22.46	39.61	—17.15	0.5	0.35	1.68	—1.33
65	40.00	....	....	3.5	2.15	....	....
50	30.44	31.21	—0.77	0.25	0.15	1.44	—1.29
33	19.44	22.43	—2.99	0.75	0.44	0.72	—0.28
18	13.64	....	....	....	....	....	....

TABLE 6. DATA FOR 1913 FROM FIELD NO. 2, PART A, TREATED IN 1912, SHOWING PERCENTAGE OF INCREASE (+) OR OF DECREASE (—) IN THE VARIOUS CLASSES OF POTATOES AND IN YIELD AS COMPARED WITH THE CORRESPONDING CHECKS

Treatment (pounds per acre)	Plat	Clean (percentage)	Scabby (percentage)	Culls (percentage)	Yield (percentage)
Sulfur 450	3	+17 91	—15 66	—2 25	— 7 60
	13	+28 33	—27 23	—1 10	—11 02
	19	+16 40	—15.16	—1 24	— 5 83
	26	+15.44	—15 07	—0 37	—18 41
	35	+ 2 06	— 0 77	—1 29	+ 7 78
Average		**+16 03±2 83**	**—14 78±2.83**	**—1 25±0.20**	**— 7 02±2.89**
Lime 350, Sulfur 450	7	— 3 19	+ 5 67	—2 48	— 0 78
	16	+ 9 16	— 8 39	—0 77	— 2.26
	30	—14 60	+13 73	+0 87	+ 4 35
Average		**— 2 88±4.63**	**+ 3 67±4.36**	**—0 79±0.65**	**+ 0.44±1.35**
Commercial fertilizer 1000, Sulfur 450	12	+11 52	—10 12	—1 40	—12.72
	24	+ 3 54	— 2 74	—0 80	— 3 56
Average		**+ 7 53±2 69**	**— 6 43±2 49**	**—1 10±0.20**	**— 8 14±3.09**
Sulfur 900	4	+26 79	—24 94	—1 85	—24 26
	15	+23 24	—22 65	—0 59	—34 21
	27	+32 86	—31 08	—1 78	—14 50
	36	+ 3 27	— 2 99	—0 28	+19 41
Average		**+21 54±4 32**	**—20 42±4.09**	**—1 12±0.27**	**—13 39±7.86**
Lime 350, Sulfur 900	9	+15 16	—11 84	—3 32	—10 22
	18	+27 44	—25 86	—1 58	—10.94
	32	+18 21	—17 70	—0 51	— 1 94
Average		**+20 27±2.49**	**—18 47±2.74**	**—1 80±0.55**	**— 7 70±1.95**
Commercial fertilizer 1000, Sulfur 900	21	+22 71	—21 31	—1 40	—17.99
	33	+18 48	—17.15	—1 33	— 7 86
Average		**+20 60±1 43**	**—19 23±1 41**	**—1 37±0 02**	**—12 93±3.42**
Lime 350	6	—17.11	+18 02	—0 91	+ 2 53
	29	—19 50	+16 78	+2 72	+ 2.95
Average		**—18 31±0.80**	**+17.40±0.42**	**+0 91±1.23**	**+ 2 74±0.14**
Commercial fertilizer 1000	10	—11 75	+13 16	—1 41	+11 69
	23	—20 60	+20 19	+0 41	+10.01
Average		**—16.18±2.99**	**+16.68±2.37**	**—0 50±0.61**	**+10.85±0.57**

both ways; so that there was exactly the same number of hills per plat, and at the same time seed pieces of a much more uniform kind could be used than is practicable when a planter is employed.

The field was sprayed, with 4-4-50 bordeaux mixture, only three times, because after the end of July the weather was extremely dry and the plants began to die.

At the time of digging, only two rows of each plat were sorted and weighed separately. The reason for doing this instead of taking three rows, as was done before, was that in digging the potatoes with hooks in the fall of 1912 the surface soil was removed from one plat to the other far enough to warrant discarding another row between the plats. Also, in

the first year on the whole slightly increases rather than decreases the yield of potatoes; except when the soil receives at the same time a heavy application of potash and phosphoric acid, in which case the effect of sulfur usually is negative. The effect of an application of sulfur of 450 to 900 pounds per acre on a second year's crop of potatoes seems to be, as a rule, that of more or less reducing the yield, except when the application of sulfur is combined with lime; the use of lime with 450 pounds of sulfur seems to prevent any decrease, and with 900 pounds of sulfur the decrease is considerably diminished (—7.7 per cent $\pm$ 1.95 per cent).

In order to ascertain, at least in a preliminary way, whether sulfur has indeed any fertilizing value for potatoes, and if so in what quantities, an experiment was conducted in the season of 1913 on the farm of Charles Wolcott, Atlanta, New York. The soil of the field is Volusia loam, one of the soils extensively used in this State for potatoes. The whole field is of a fairly uniform nature, but slightly sloping northward. It comprises only a small area in the whole potato field, and there was no opportunity to arrange the plats otherwise than along the slope in conformity with other rows in the field. At the time of beginning this experiment there seemed to be no special objection to such an arrangement; but, as the data show, the yield was in places extremely variable, perhaps because of slightly greater or less seepage of the subsoil water — which might have an unusually important effect on the crop during that exceptionally dry season.

The general trend of the data obtained from this experiment seems to indicate definitely: (1) that the application of about 100 pounds of sulfur per acre somewhat increases the yield; (2) that applications of 50, 200, and 300 pounds of sulfur per acre have more or less neutral effect on the yield; and (3) that the yield was materially decreased when sulfur was applied at the rate of 500, 700, and 900 pounds per acre.

The results obtained are somewhat in accord with some of the work briefly mentioned above on the fertilizing value of sulfur, and therefore might be accepted as final; but since on the whole the data are too irregular to allow drawing any final conclusions, they are not given here.

It is evident that a series of careful and thorough experiments along these lines is much needed; and, according to Thatcher (1912), some work laid out on an exceptionally broad plan has been carried on by the United States Department of Agriculture, but no results have as yet been published.

GENERAL SUMMARY OF WORK DONE

From our work on sulfur treatment of the soil against potato scab it is evident that by application of sulfur in a sufficient quantity — 450 to 900 pounds per acre — if the application is made broadcast and the sulfur is

thoroughly mixed with about two inches of the surface soil just before potatoes are planted, the amount of scab can be considerably reduced, especially by the heavier application of sulfur. This is true at least in case of the soils of the Dunkirk series commonly used for potato culture. In no case, however, even by the heaviest of the tested applications of sulfur, was the scab entirely eliminated.

When lime was applied at the rate of 350 to 400 pounds per acre, together with 450 pounds of sulfur per acre, the fungicidal power of the latter was in some cases reduced to nearly nil; while the same quantity of lime with 900 pounds of sulfur did not reduce the fungicidal value of sulfur at all, and at the same time diminished the injurious after effect of sulfur treatment on the crop.

As a rule, the effect of sulfur treatment on the same crop in the next succeeding season is that of reducing yield and scab, the scab being reduced more than the yield.

Sulfur added to commercial fertilizer reduces the value of the fertilizer more or less noticeably.

A small quantity of sulfur—about 100 pounds per acre—may prove to be of fertilizing value for potatoes, at least on certain soils, for which at the same time sulfur in quantities over 300 pounds per acre appears to be more or less injurious to the same crop.

As a general remark in regard to the actual effect of sulfur treatment on scab, it is proper to call attention here to the fact that the mere percentage of increase or decrease, as the case may be, of the scabby tubers, as shown in our data, does not give a fair idea of the actual effect of the treatment on the extent of the scab injury. A tuber with only one scab spot and one with several would be in the same lot of scabby tubers. And, as a rule, the greater the number of scabby tubers, the greater is the extent of the injury; so that when a treatment reduces the total amount of scab—for example, from 40 to 20 per cent—the actual reduction usually is much greater than 20 per cent because the scab injury in the latter case is not so intense as in the former.

Grading of the tubers according to the extent of the injury into several classes would, of course, help much to record this difference; but such grading of the tubers is not practicable under the conditions of an extensive field experiment.

The effect of sulfur treatment on the percentage of culls—that is, the tubers very badly scabbed—has not been discussed in this paper at all because the percentage of culls was small and therefore did not present good material for comparative study of the effect of the various treatments. From the tables given in this work, however, it is evident that the decrease in the number of culls was at least as great as that in the scabby potatoes.

LITERATURE CITED

Bernhard, Ad.
1910 Versuche zur bekämpfung des kartoffelschorfes. Deut. landw. presse **37**: 204–205.
1911 a Feldversuche gegen den kartoffelschorf. Deut. landw presse **38**: 168–169, fig. 146–148; 179–180, fig. 154.
1911 b Gefassversuche zur bekämpfung des kartoffelschorfes. Deut. landw. presse **38**: 320, fig. 262–268.

Bolley, H. L.
1891 Potato scab, and possibilities of prevention. North Dakota Agr. Exp. Sta. Bul. 4: 3–14, 21–31.

Boullanger, E., et Dugardin, ——
1912 Mécanisme de l'action fertilisante du soufre. Acad. Sci. Paris. Compt. rend. **155**: 327–329.

Brooks, W. P.
1897 Scab of potatoes. Massachusetts (Hatch) Agr. Exp. Sta. Rept. **9**: 44–45.

Chester, F. D.
1897 The treatment of plant diseases in 1896. Delaware Agr. Exp. Sta. Bul. 34: 19–20.
1898 Experiment in the use of sulphur for scab of the Irish potato. Delaware Agr. Exp. Sta. Rept. **10**: 45–46.

Cunningham, G. C.
1912 The relationship of Oospora scabies to the higher bacteria. Phytopath. **2**: 97.

Demolon, A.
1912 Sur l'action fertilisante du soufre. Acad. Sci. Paris. Compt. rend. **154**: 524–526.
1913 Recherches sur l'action fertilisante du soufre. Acad. Sci. Paris. Compt. rend. **156**: 725–728.

Feilitzen, H. von
1913 Employment of flowers of sulphur as protection against potato scab and as indirect fertilizer. Fühling's Landw. ztg. **62**: 231–242. Cited Exp. sta. rec. **29**: 646.

Garman, H.
1898 Corrosive sublimate and flour of sulphur for potato scab. Experiments made in 1896. Kentucky Agr. Exp. Sta. Bul. 72: 9–17.

Goff, E. S.
1893 Can potato scab be prevented by treating the seed with sulphur? Wisconsin Agr. Exp. Sta. Rept. **9**: 280–281.

Güssow, H. T.
1913 Powdery scab of potatoes. Phytopath. **3**: 18–19, pl. IV.
1914 The systematic position of the organism of the common potato scab. Science **39**: 431–433.

Halsted, B. D.

1895 Field experiments with potatoes. New Jersey Agr. Exp. Sta. Bul. 112:3–20.

1897 a Field experiments with potatoes for 1896. New Jersey Agr. Exp. Sta. Bul. 120:3–19.

1897 b Experiments with potatoes. New Jersey Agr. Exp. Sta. Rept. **17**:309–328.

1898 Experiments with potatoes. New Jersey Agr. Exp. Sta. Rept. **18**:276–284.

1899 a Experiments with potatoes. New Jersey Agr. Exp. Sta. Rept. **19**:299–309.

1899 b Mycological notes. Bul. Torrey Bot. Club **26**:72–78.

1900 Soil fungicides for potato and turnip diseases. New Jersey Agr. Exp. Sta. Rept. **20**:326–345.

1901 Potato experiments in 1900. New Jersey Agr. Exp. Sta. Rept. **21**:413–418.

Hart, E. B., and Peterson, W. H.

1911 Sulphur requirements of farm crops in relation to the soil and air supply. Wisconsin Univ. Agr. Exp. Sta. Research bul. **14**:1–21.

Jones, L. R., and Edson, A. W.

1901 Potato scab experiments of 1901. Vermont Agr. Exp. Sta. Rept. **14**:231–233.

Jones, L. R., and Morse, W. J.

1904 Potato diseases and their remedies. Vermont Agr. Exp. Sta. Bul. 106:230–235.

Lutman, B. F.

1913 The pathological anatomy of potato scab. Phytopath. **3**:262.

Lyon, T. L.

1912 Some experiments to estimate errors in field plat tests. Amer. Soc. Agron. Proc. **3**:89–114.

Marès, H.

1869 Des transformations que subit le soufre en poudre (fleur de soufre et soufre trituré) quand il est répandu sur le sol. Acad. Sci. Paris. Compt. rend. **69**:974–979.

Mercer, W. B., and Hall, A. D.

1911 The experimental error in field trials. Journ. agr. sci. **4**:107–132.

Morse, W. J.

1912 Does the potato scab organism survive passage through the digestive tract of domestic animals? Phytopath. **2**:146.

1913 Powdery scab of potatoes in the United States. Science **38**:61–62.

Pammel, L. H.

1895 Potato scab and its prevention. Iowa Agr. Exp. Sta. Bul. 27:120–129.

Pethybridge, Geo. H.
1912 Investigations on potato diseases. Department of Agriculture and Technical Instruction for Ireland. Journ. **12**:334–360.
1913 Investigations on potato diseases. Department of Agriculture and Technical Instruction for Ireland. Journ. **13**:445–468.

Pollacci, E.
1874 Intorno all'azione dello zolfo sui carbonati terrosi, e particolarmente su quello neutro di calcio, con cenni reguardanti la geologia e l'agricoltura. Gaz. chim. Ital. **4**:245–256.

Sturgis, W. C.
1897 On the susceptibility of various root-crops to potato-scab and the possibility of preventive treatment. Connecticut Agr. Exp. Sta. Rept. **20**:263–266.

Taft, L. R.
1890 Potato scab. Michigan Agr. Exp. Sta. Bul. 57:23–25.

Thatcher, R. W.
1912 United States Agr. Dept., Exp. Sta. Office. Rept. **1911**:218.

Thaxter, Roland
1891 The potato "scab." Connecticut Agr. Exp. Sta. Rept. **1890**:81–95.
1892 Potato scab. Connecticut Agr. Exp. Sta. Rept. **1891**:156.

Wheeler, H. J., and Adams, G. E.
1898 On the use of flowers of sulfur and sulfate of ammonia as preventives of the potato scab in contaminated soils. Rhode Island Agr. Exp. Sta. Rept. **10**:254–268.

Wheeler, H. J., Hartwell, B. L., and Moore, N. L. C.
1899 Upon the after effect of sulfur, when applied to soils for the purpose of preventing potato-scab. Rhode Island Agr. Exp. Sta. Rept. **12**:163–167.

Wheeler, H. J., and Tucker, G. M.
1896 Potato scab. Rhode Island Agr. Exp. Sta. Bul. 40:80–96.

Wood, T. B., and Stratton, F. J. M.
1910 The interpretation of experimental results. Journ. agr. sci. **3**:434–440.

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CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Soil Technology

In Cooperation with the Bureau of Soils, U. S. Department of Agriculture

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SOIL SURVEY OF ORANGE COUNTY

NEW YORK

By G. A. CRABB, of the United States Department of Agriculture
and T. M. MORRISON, of Cornell University

Under the direction of
ELMER O. FIPPIN

ITHACA, NEW YORK
PUBLISHED BY THE UNIVERSITY

RESOLUTION PROVIDING FOR THE FEDERAL PUBLICATION AND DISTRIBUTION OF SOIL SURVEY REPORTS

[PUBLIC RESOLUTION — No. 9]

JOINT RESOLUTION amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided,* That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the Congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]

EXPLANATORY STATEMENT

The subjoined is a report on the Soil Survey of Orange County, accompanied by a large scale map in colors showing the distribution of the several types of soil recognized and described. This survey was made by George A. Crabb, representing the Bureau of Soils of the United States Department of Agriculture, and Tracy M. Morrison, representing the Department of Soil Technology of this College. The work was done in cooperation with the United States Bureau of Soils, of which Milton Whitney is Chief, Curtis F. Marbut is in charge of Soil Survey, and J. E. Lapham is Inspector of the Northern Division. A limited edition of this report is published by the United States Department of Agriculture as a separate from the Field Operations of the Bureau of Soils, but this College has none of these reports for distribution.

BEVERLY T. GALLOWAY,
Director.

CONTENTS

ILLUSTRATIONS

FIGURE

MAP

SOIL SURVEY OF ORANGE COUNTY, NEW YORK

By G. A. CRABB, of the U. S. Department of Agriculture, and T. M. MORRISON, of the New York State College of Agriculture

DESCRIPTION OF THE AREA

Orange County is located in the southeastern corner of New York State. It is irregular in outline, and comprises 834 square miles, or

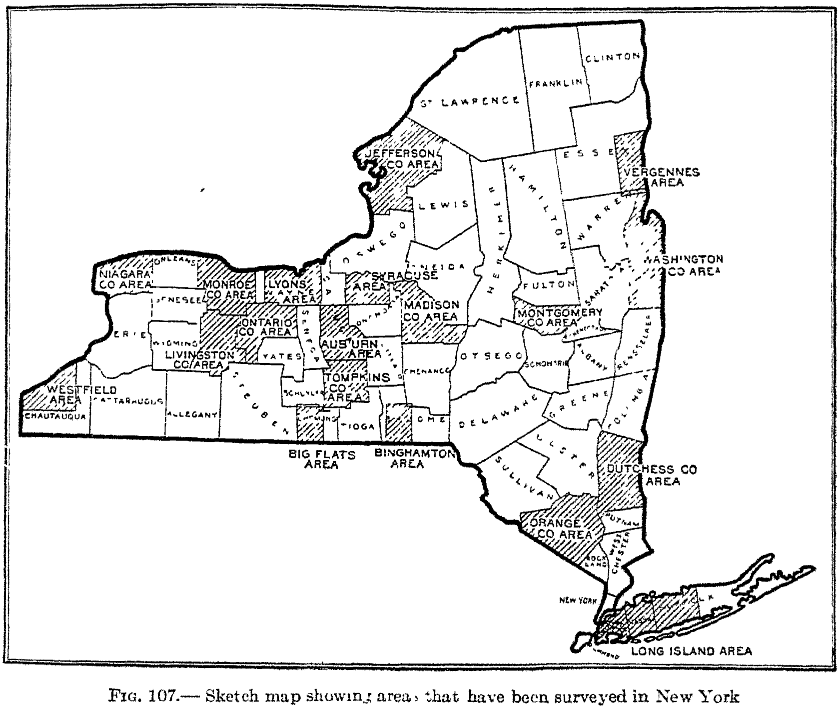

FIG. 107.— Sketch map showing areas that have been surveyed in New York

533,760 acres. It is bounded on the east by Dutchess, Putnam, and Westchester Counties, from which it is separated by the Hudson River, and on the southeast by Rockland County. The southwestern boundary is formed by the New Jersey and Pennsylvania State lines, the latter formed by the Delaware River, separating Orange County from Passaic and Sussex Counties, N. J., and Pike County, Pa. It is bounded on the west and north by Sullivan

and Ulster Counties, N. Y. On the extreme western boundary Mongaup River marks the division between Orange and Sullivan Counties, while on the northwest these counties are separated by the Shawangunk Kill.

The surface features of Orange County are diversified. They vary from the level "drowned lands" of the Wallkill River to the rugged peaks and ridges of the Highlands. The greater part of the county is included in a country of hills and ridges and of broader valleys with more even topography. The elevation ranges from sea level on the Hudson, which has tidal flow, to 1,680 feet on Schunemunk Mountain. In general average elevations vary from 800 to 1,200 feet in the mountainous sections to 300 to 500 feet in the Wallkill-Newburgh Valley.

The surface of the entire county has been modified by glacial action. The region most influenced by glaciation is that west of Newburgh, where the glacial drift has a depth of 500 feet or more. The section least affected is in the Highlands along the Hudson River, about the Schunemunk and other mountains in the southeastern part of the county, the Shawangunk Mountains in the west-central part, and the Catskill Plateau west of the Neversink River.

Broadly, Orange County comprises four physiographic divisions, the large, broad valley extending from northeast to southwest through the central part of the county, bordered by hills and ridges, with small streams between, the mountains of the Highlands on the southeast, the Shawangunk Mountains on the northwest, and west of the Shawangunk range the Catskill Plateau, which is separated from the mountains on the east by the Neversink River Valley.

The southeastern part of the county, including the Highlands, is the most extensive mountainous section. The Highlands consist of a number of separate ranges which rise abruptly from the Hudson River on the east. The principal mountain ranges are the Stockbridge, Goshen, Letterrock, Bellvale, and Warwick Mountains. Storm King is one of the principal peaks. The ranges also include Bear Mountain, Stevens Mountain, Black Mountain, Rascal Mountain, and Black Rock Hill. The elevations range from about 1,200 feet to 1,500 feet above sea level. This Highlands region is broken by the Ramapo River and Greenwood Lake valleys and by numerous small streams. On the New Jersey line near the Wallkill are the Pochuck Mountains, and farther north are Mount Adam and Mount Eve, all of granitic rock. The Schunemunk Mountains are separated from the Highlands by Woodbury Creek. These mountains are very abrupt and broken. The land is nonagricultural, and it is for the most part classified as Rough stony land and Rock outcrop.

In the western part of the county, just to the east of the Neversink River Valley, are the Shawangunk Mountains. These mountains

consist of a series of ridges extending in a northeast-southwest direction, separating Deer Park from the remainder of the county. Their altitude varies from 1,300 to 1,400 feet above sea level.

The entire region west of the Shawangunk Mountains is of little value agriculturally, with the exception of the Neversink River Valley, which is extensively cultivated.

The uplands for the most part constitute a somewhat broken plateau extending southwest from the Catskill region. This part of the county is hilly and ridgy, with some extensive areas of fairly regular topography. It includes a number of streams with narrow valleys. The ridges and hills are often composed of Rock outcrop, or are very rocky and broken. The elevated areas rise abruptly from the Neversink, Mongaup, and Delaware Rivers.

Granite has been quarried at different points in the Highlands and on Pochuck Mountain near the New Jersey line. Limestone is available for building purposes, road making, and for the manufacture of lime. It is widely distributed throughout the central part of the county. Flagging stone is obtained quite extensively on the plateau west and north of Port Jervis. The clays along the Hudson River are extensively used for building brick, the manufacture of which constitutes an important local industry. Clay from deposits in other parts of the county is used for the manufacture of brick and drain tile. Iron mining was an important industry at one time, particularly in the Highlands section of the county, but practically all of the iron mines have been abandoned. Zinc and lead mines have been operated at various places and arsenical deposits also have been worked.

The great central valley, which extends from the Hudson River on the east to the Shawangunk Kill and the Shawangunk Mountains on the west, consists of rolling upland broken by hills, ridges, and valleys. The hills and ridges have been smoothed and rounded by glacial action and are quite regular in surface features. Numerous small, abrupt peaks or ridges are found. The valleys are generally broad.

This central valley is divided by Wallkill River, a retrograde stream which enters the county from New Jersey on the south near Unionville, flows northeast across Orange County, entering Ulster County at a point just north of Walden and emptying into the Hudson River near Kingston. The Wallkill and its tributaries carry a large part of the drainage of Orange County. The river has a wide valley and many streams flow into it. The most important of its many tributaries are Pochuck, Quaker, and Rutgers Creeks, Muddy Kill, and Tin Brook. For several miles the Wallkill flows through the extensive area known as the "drowned lands." Along

this part of the stream the current is quite sluggish and the river course is extremely meandering. The "drowned lands" are naturally poorly drained and for many years were impassable swamps. By straightening the course of the river and constructing new channels to carry off the excess water these lands have been made the most valuable of any in the county.

Other important drainage ways are the Shawangunk Kill, which flows in a general northeast direction and for several miles forms the boundary between Orange and Sullivan Counties, Indigot Creek, which empties into Rutgers Creek, and the Dwaar Kill, which flows northeast into Ulster County. Wawayanda Creek flows southwest, passing through the town of Warwick into New Jersey.

In the eastern part of the county Moodna Creek, Woodbury Creek, and the Otter Kill are the principal streams. Gidneytown Creek and Quassaic Creek are the main drainage ways of the northeastern part of the county. Bushfield Creek empties into Orange Lake, whose outlet is Quassaic Creek. The southeastern section of the county is drained either directly by the Hudson River or by the Ramapo River, the outlet of Tuxedo Lake, which flows southward into New Jersey. West of the Shawangunk Mountains all of the drainage is into the Delaware River through the Neversink River and its main tributary, the Basher Kill, and through the Mongaup River on the west.

All of the drainage waters of Orange County are received by the Hudson and Delaware Rivers.

There are numerous lakes in Orange County, which are largely used for municipal water supply. While many of these lakes are the sources of streams, a few have no visible outlet.

Orange County was organized in 1683, and at that time it comprised areas now included in Rockland and Ulster Counties. The boundaries of the county were changed several times and were definitely established in 1801.

At the time of its organization Orange County was inhabited by only a few scattered families, mainly along the Hudson River. Settlement extended into the interior of the county about 1690 and a census taken in 1698 shows a total population of 219. Since the beginning of the eighteenth century the population of Orange County has had a remarkably steady growth.

In character and origin the population is quite varied. The earliest settlers were Dutch, English, French, German, Irish, and Scotch, and subsequent immigration was largely from the New England settlements. The present population consists largely of descendants of these early settlers. During recent years there has been a steady immigration of foreigners, who, as a rule, find employ-

ment in the manufacturing industries, though a great many are working on the farms, especially on the Muck soils in the vicinity of Florida, Pine Island, Big Island, and Durlandville, where trucking is important. The present foreign element is composed of Poles, Hungarians, Swedes, Norwegians, and Italians. There are some negroes in the county, mainly in the towns, although a part of the negro population furnishes farm labor.

Orange County is less thickly settled in the southeastern and western mountainous regions than in other sections. According to the 1910 census, the county has a population of 116,001. In 1900 it was reported as 103,859, and in 1890 as 97,859. Goshen, with a population of 3,081, is the county seat. It is situated on the main line of the Erie Railroad near the center of the county. Goshen is the terminal of the Montgomery and Pine Island branches.

Newburgh is the largest city in the county, having a population of 27,805. It is located on the Hudson River and is on the West Shore and the Erie Railroad. The main line of the New York Central & Hudson River Railroad is available at Fishkill, on the opposite side of the Hudson, by means of the ferries. Middletown and Port Jervis, with populations of 15,313 and 9,564, respectively, are important places because of their manufacturing industries.

The many varied industries of Orange County include bleacheries, iron foundries, and shipyards. Soap, wire, chairs, lace curtains, cotton goods, ice machines, engines, cement, and plaster are manufactured. One of the largest lawn-mower factories in the world and a large factory for the manufacture of fabrikoid, or imitation leather, are located within the county. The manufacture of woolen goods, the distilling of liquors, and the manufacture of paper were important industries at one time.

The transportation facilities of Orange County are good. The Hudson River furnishes cheap freight and passenger service between the county and its largest market, New York City, and to many local points. The freight boats on the Hudson River carry the bulk of all freight within reach of shipping points, with the exception of milk, which is generally carried by rail.

A number of railroads traverse different parts of the county. All of these roads provide special daily milk trains to the large markets in New York City. Special trains are also furnished for the truckers for transporting produce from the extensive trucking districts near Florida, Chester, and Pine Island. Two electric roads are also in operation within the county, and one—the Orange County Traction Line—carries passengers and operates freight and express cars.

The public roads are kept in good condition. There are many miles of excellent State highway connecting nearly all of the towns.

Owing to the good condition of the roads, transportation is easy, and little difficulty, aside from that caused by a few hills where the grade is steep, is experienced in marketing farm products.

A large number of excellent markets are available to Orange County; local manufacturing and industrial centers constitute ready markets for all agricultural products. The principal markets within the county are Newburgh, Goshen, Middletown, Walden, and Port Jervis. Practically all of the products of Orange County not consumed locally are shipped to New York City, which is only about 70 miles distant from the most remote parts of the county.

CLIMATE

A fair idea of the general climatic conditions of Orange County is given by the tables below, the figures being compiled from data recorded at the Weather Bureau station at Port Jervis, lying at an elevation of 470 feet, and at West Point, at an elevation of 167 feet.

Normal monthly, seasonal, and annual temperature and precipitation at Port Jervis

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year	Snow, average depth [1]
	°F.	°F.	°F.	Inches	Inches	Inches	Inches
December	28.2	66	−11	3.60	1.88	3.86	11.2
January	24.1	67	−20	3.38	2.65	3.00	10.1
February	25.2	69	−14	3.59	2.73	4.37	15.0
Winter	25.8			10.57	7.26	11.23	36.3
March	33.9	88	−8	3.52	2.94	3.68	9.6
April	47.0	92	14	3.12	4.25	3.52	2.1
May	59.5	94	26	4.25	1.22	1.00	0.0
Spring	46.8			10.89	8.41	8.20	11.7
June	67.4	96	38	4.01	2.31	13.76	0.0
July	71.0	103	42	5.16	3.90	4.50	0.0
August	69.1	100	40	4.33	3.29	8.25	0.0
Summer	69.2			13.50	9.50	26.51	0.0
September	62.9	95	29	3.79	2.53	1.52	0.0
October	50.7	88	20	3.59	1.70	10.60	0.0
November	38.5	73	8	2.94	2.50	1.99	3.4
Fall	50.7			10.32	6.73	14.11	3.4
Year	48.1	103	−20	45.28	31.90	60.05	51.4

[1] Snowfall data are for the period from 1880 to 1903. Other data from 1880 to 1909.

Normal monthly, seasonal, and annual temperature and precipitation at West Point

Month	Temperature			Precipitation		
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year	Total amount for the wettest year
	° F.	° F.	° F.	*Inches*	*Inches*	*Inches*
December	31.4	65	−2	3.55	2.89	2.26
January	27.7	64	−15	3.48	1.70	3.27
February	28.4	56	−11	3.38	1.00	5.45
Winter	29.2			10.41	5.59	10.98
March	36.4	72	−1	3.64	2.40	3.23
April	48.6	93	18	3.68	1.70	5.84
May	59.9	95	28	4.48	2.41	7.99
Spring	48.3			11.80	6.51	17.06
June	69.6	99	39	3.53	3.18	3.77
July	74.0	103	40	4.62	1.10	10.48
August	72.2	97	35	4.61	4.57	7.87
Summer	71.9			12.76	8.85	22.12
September	64.8	99	30	3.72	2.78	3.95
October	53.4	90	20	3.76	2.18	3.85
November	42.0	73	5	3.92	4.73	5.60
Fall	53.4			11.40	9.69	13.40
Year	50.7	103	−15	46.37	30.64	63.56

There is quite a wide range in the temperature of the county, the tables showing an absolute maximum of 103° F. and an absolute minimum of −20° F. A mean annual temperature of 48.1° is recorded at Port Jervis and of 50.7 at West Point. The county has a heavy snowfall, averaging 51.4 inches annually at Port Jervis. The snowfall is practically confined to the winter and spring months, and is heaviest in February. The rainfall is fairly heavy and is generally well distributed throughout the growing season, although at times crops suffer from excessive precipitation or from drought at critical stages or during harvest time. The rainfall is greatest during the summer months, the mean precipitation for this period being 13.50 inches at Port Jervis and 12.76 at West Point. The means for the spring and winter months are about equal. There is a wide variation, however, between the annual precipitation for the driest and wettest years, the figures being 31.90 to 60.05 inches, respectively, at Port Jervis, and from 30.64 to 63.56 inches at West Point.

The average length of the growing season is approximately 161 days. At Port Jervis the average date of the last killing frost in the spring is April 30 and of the first in the fall October 10, while the latest date recorded in the spring is May 17 and the earliest recorded in the fall is September 15. The average date of the last killing frost in the spring, according to the records of the West Point station, is April 20, and of the first in the fall October 17, while the latest date recorded at this station in the spring is May 6 and the earliest recorded in the fall September 28.

Since the growing season in Orange County is limited mainly by the occurrence of killing frosts, this is a matter of importance to the farmers, and with a view to the protection of crops considerable attention is given to the exposure or slope of the land, the elevation, the physical properties and water content of the soil, and the air drainage.

The southern exposures are the warmest, the southeastern next, with the eastern, southwestern, and western, in order, the northern exposures being the coldest. With reference to liability to frosts these exposures may be arranged in opposite order, with the northern most liable and the southern exposures the least liable. This does not mean that a southern exposure is always best for the planting of crops, especially fruit, because the higher temperature resulting from exposure to the more direct rays of the sun often tends to bring out the buds too early and increases the danger of killing by late frosts. One of the best protected orchards in the county, where loss by frost is probably least likely to occur, is on an eastern exposure with a high hill to the west. The failures of fruit crops in this orchard have been rare.

In poorly drained and poorly cultivated areas crops are more subject to damage by frost than in areas where the soil is kept well drained and in good physical condition. Frosts are more destructive in the valleys than in the upland.

AGRICULTURE

Throughout the history of the county the most important agricultural area has been the central belt, including the area in which the Dutchess and Dover soils predominate. The country occupied by Culvers soils, especially the large area lying west of the Basher Kill Valley, is not and apparently never has been of any agricultural importance. The latter area now supports a second growth of oak and chestnut brush and has very little value for anything but cordwood. The eastern part of the county, that part included in what is usually known as the Highlands, is also of very little agricultural

importance. The eastern slope of Shawangunk Mountain is extensively cultivated, but this area does not rank with the central belt of the county in production.

In general, the farming and stock-raising industries, as well as dairy farming, are well distributed over the agricultural part of the county, dairying being more prominent near the railways and stock raising and grain farming predominating in more distant sections. Similarly, the production of apples is widely distributed over the agricultural area of the county. The growing of small fruits, however, as well as the main part of the area in peach orchards, is confined to the eastern, mainly the northeastern, part of the county, though more or less development has taken place at other points in the Hudson River hills.

Prior to the settlement of Orange County, the aborigines of the region were engaged in the cultivation of corn. Immediately after establishing their homesteads the early settlers commenced the practice of agriculture.

The original forest growth consisted of oak, chestnut, butternut, hickory, willow, beech, birch, elm, mulberry, several varieties of pine, hemlock, cedar, tamarack, and cherry. Areas in the agricultural section were cleared, the timber being used for houses and fences and for the manufacture of charcoal and pot and pearl ashes. Some lumber was exported, and some of the timber was used in shipbuilding.

The early settlers began by growing whatever crops were needed to furnish food and clothing for themselves. After the county became more thickly settled additional crops were grown for market, but agricultural progress was slow, considerable attention being given to manufacturing. Wheat and corn were the earliest crops grown. These were the staple articles of food. Flax was grown for the manufacture of clothing. Wild blackberries, raspberries, and strawberries were abundant. Orchards of apples, pears, and cherries were planted. Sheep and cattle were raised, the wool produced being used for clothing and the hides for leather. With the development of farm lands in the western part of the State and in other States in the West, wheat became less prominent. The live stock industry was more important in the central and western parts of the county, where good pasture land was available, than along the Hudson River, because travel was more difficult and transportation facilities meager, and stock could be grown, fattened, and driven to market more easily than grains could be handled.

The live stock industry has always been of great importance, but it is not so extensive now as in the past. Dairying and horse raising are the principal branches of this industry now practiced, while poultry is also important.

The total value of live stock increased from $1.953,092 in 1850 to $4,672,529 in 1870. In the 1900 census the value of domestic animals is given as $3,347,806, while in 1910 it is reported as $4.654.754.

Dairying is the most important of the live stock industries. The value of dairy products is reported as $669,866 in 1840, while $3,537,640 was received from the sale of such products in 1909. Prior to 1842 the greater part of the milk was converted into butter. The greatest amount of butter produced is reported by the 1840 census, in which the total is given as 3,769,034 pounds. Very little cheese was produced at that time. The amount of butter produced decreased steadily until in 1900 only 327,057 pounds were made. The 1910 census reports a production of 212,111 pounds. The production of cheese has never been a prominent feature of the dairy industry. The greatest amount produced, as given by the census, is 33,800 pounds in 1870.

Since 1842 the production and sale of milk has gradually supplanted other phases of dairying. The shipment of milk began with the opening of the Erie Railroad. At the outset the principal dairy section was that between Otisville and Arden. At present milk is shipped from all parts of the county, with the exception of the roughest and most remote sections. Shipping stations, skimming plants, and creameries are distributed throughout the county and solid milk trains carry milk from all points to the large markets every day. The greatest amount of milk produced in any year, according to the census, was in 1900, when it reached 31,889,010 gallons, of which 29,617,072 gallons were sold. In 1910, 23,905,147 gallons were produced.

There are many herds of pure-bred cattle in the county, though for the most part the dairy cattle are grades. The pure-bred herds include Holsteins, Jerseys, Guernseys, and other dairy breeds. The Holstein is the most popular breed. In the 1910 census a total of 45,882 dairy cows is reported.

Horse raising has for many years received considerable attention. It consists for the most part now in the raising of light harness horses, race horses, and fancy carriage horses. Excellent pastures are available in many parts of the county.

The poultry industry is an important branch of agriculture. In 1910 the total value of poultry is reported as $209,660.

In the census for 1840 a total of 47,084 hogs was reported in Orange County. Since that time the number has decreased, with some fluctuation, and in 1910 only 8,838 hogs were reported. When the greatest number of hogs were raised the dairy industry was confined largely to butter making and the production of cream, so that an abundance of skimmed milk and buttermilk was left on the farms and was used as feed. With the increase in the amount of milk shipped the number of hogs raised has decreased.

The sheep industry has likewise undergone very decided changes. In 1840 a total of 50,218 sheep were reported in Orange County, and 108,876 pounds of wool were produced. In 1850 the number of animals had dropped to 23,562, and the wool produced to 47,438 pounds. The industry has never been revived. The 1910 census reports only 3,904 sheep in the county. However, the wool produced per head has increased somewhat. The farms of Orange County are well suited for the raising of sheep, provided barns are available for their protection during severe winter weather. The hills and valleys make excellent pasture land, and any grain and hay necessary can be grown. Owing to the nearness of the markets of New York and Boston, the raising of winter lambs could be made a profitable special industry.

The production of hay in Orange County has gradually increased during the past 70 years. In 1840 a yield of 75,368 tons is reported. In the 1910 census a production of 138,241 tons from 109,520 acres is reported.

Corn is the only one of the grains that has increased in the total amount produced and in the acre yield. According to the census for 1840, 410,194 bushels were produced. The 1850 census reports 491,074 bushels, and the 1870 census 459,343 bushels. According to the 1880 census 619,753 bushels were produced, 19,427 acres being devoted to the crop. In 1890 a yield of 365,098 bushels from 10,209 acres is reported, and in 1900, 589,730 bushels from 13,584 acres. In 1910, 10,479 acres were devoted to corn, with a production of 451,179 bushels. The average yield per acre increased from about 30 bushels in 1870 to about 43 bushels in 1900. A large part of the corn crop is used as feed for stock, mainly as a green feed in late summer and early fall, and as silage.

The production of oats has decreased. In 1840, 417,701 bushels were produced. The 1910 census reports a yield of only 114,215 bushels from 4,749 acres.

Rye has decreased steadily in the total amount produced. In 1840, 326,668 bushels are reported, and in 1910 only 48,960 bushels were produced from 2,777 acres. In 1890 a yield of 74,388 bushels from 5,194 acres is reported. In 1900, 4,433 acres were devoted to rye, with a production of 72,980 bushels.

In 1840 a production of 94,774 bushels of wheat is reported. The highest yield of wheat, 103,196 bushels, is reported in the 1870 census. The 1900 census reports a production of 42,430 bushels from 2,844 acres, and the 1910 census 24,190 bushels from 1,281 acres.

Buckwheat is grown to a considerable extent, though, as in the case of most of the other grains, the total production has declined. In 1840 a production of 112,883 bushels is reported. The crop was grown on 1,028 acres in 1890, with a yield of 12,956 bushels. This

increased to 23,640 bushels in 1900 from 1,383 acres, but the 1910 census reports only 17,782 bushels from 940 acres.

Potatoes are grown to some extent, but the average yield is low. The greatest total production was reported in 1840, when the yield amounted to 359,563 bushels. Only 288,341 bushels were produced in 1909 from 3,063 acres. In 1900 the yield was 312,373 bushels from 3,544 acres.

The onion crop has become important, being confined to the Muck areas. In 1900 a production of 783,781 bushels from 1,571 acres is reported.

The production of nursery stock and flowers receives considerable attention.

Alfalfa is successfully grown and has proved valuable as a feed for dairy cattle. This crop can be grown on much of the upland and requires a carefully prepared seed bed on land which has well-developed internal drainage, either natural or artificial. The application of lime in amounts varying from 1,000 to 1,500 pounds per acre on the light sandy soils to 2,000 or 3,000 pounds on the stony loams or silt loams is generally necessary. Best results are obtained where the land is inoculated with soil from an alfalfa field at the rate of 200 or 300 pounds per acre. The inoculation of limestone soils is not generally considered necessary. Where the land needs lime and inoculation the addition of manure before plowing is beneficial, as this insures a stand of alfalfa. The best time for seeding is during the first part of August. This permits the alfalfa to make a good growth before winter commences.

Soy beans are an excellent crop to be used in connection with corn for silage.

Orcharding is an important branch of agriculture in Orange County. Many of the soils are specially adapted to the production of fruit, and owing to the excellent shipping facilities available this is a profitable industry. Both the large and small fruits are grown extensively. The total value of orchard products reported in the 1900 census was $231,463. In the 1910 census the total value of fruits and nuts is given as $382,505. The census for 1910 reports 122,633 apple trees, 212,879 peach and nectarine trees, 33,098 pear trees, 7,863 cherry trees, and 11,479 plum and prune trees, with a production in 1909 of 277,355 bushels of apples, 124,262 bushels of peaches and nectarines, 21,994 bushels of pears, 3,635 bushels of cherries, and 4,617 bushels of plums and prunes. In addition 200,733 grape vines are reported. The 1900 census reports 240 acres in strawberries, with a yield of 383,100 quarts, and 232 acres in raspberries and loganberries, producing 361,360 quarts. The 1910 census gives the production of strawberries as 795,411 quarts from 310 acres, and of raspberries and loganberries as 274,352 quarts from 156 acres. The greatest problem

encountered in the fruit industry is that of securing labor during the picking season.

Farming is now more specialized than at any time in the history of Orange County. It is largely divided between dairying, fruit raising, and trucking. Dairying is the principal industry, and the crops grown, consisting largely of hay and forage, are those that are needed to supply the dairies. Most of the grain fed, however, is shipped into the county. Trucking on the Muck lands represents the most intensive farming.

Some income is derived from forested areas, mainly in the production of cordwood and railroad ties. The 1900 census reports the value of forest products as $94,295.

The adaptation of soils to crops is recognized to some extent by the farmers of the county. Areas of the rougher hill country and the low, wet valley lands are used for permanent pasture. The bottom land, while generally too wet in the spring, furnishes excellent pasture in midsummer, when the hill lands suffer most from drought. Fields of light sandy soils and the thin soils are used largely for rye. Oats, corn, and potatoes are generally grown on both the upland and valley soils. Areas of the stony upland soils or of shale loam, where the drainage is good, are devoted mainly to orchards, which are given less cultivation than the ordinary crops. The Dutchess stony loam and shale loam are the types most extensively used for fruit growing. The value of the gravelly and sandy types as early soils is generally recognized. General farming and dairying are practiced on nearly all of the types, sometimes being confined to one type, and in other cases being carried on on a number of types in combination. The Muck soil is largely devoted to trucking, to which purpose it is well adapted. Special crops of onions, lettuce, celery, carrots, potatoes, etc., are grown extensively, and the land has a high value. The areas of rough topography are mainly forested. In some cultivated areas the surface is so uneven that the land is best adapted to forestry.

A large part of each farm is generally kept in grass, for use as permanent pasture. Timothy is the most popular grass. Redtop, clover, and alfalfa are grown.

But little effort is made by the farmers of Orange County to develop systematic crop rotations. The rotation commonly followed is corn one year and rye or oats the following year, the land then being seeded to grass or timothy, or a combination of timothy and clover to be cut for hay three or four years or more, and then used as pasture for as much longer. Many areas used for meadow and pasture have not been plowed for the last 10 years, and some for even a longer time. Some of the pastures have been permitted to remain in sod for so long that nearly all of the cultivated grasses sown

have been displaced by the wild native species. While the general plan of this rotation is good, the sod is usually allowed to remain too long. The most satisfactory practice is to apply a top dressing of manure to be plowed under at the end of the fourth or fifth year.

Fertilizers are not extensively used, except on the Muck lands, where they are applied in large quantities, ranging from 500 to 2,000 pounds per acre, according to the crop and the condition of the soil. The 1900 census reports an expenditure of $63,150 and the 1910 census an expenditure of $130,088 for fertilizers in Orange County. On the dairy farms the manure produced is applied to the soil.

In general the greatest problem confronting the farmer of Orange County is that of securing satisfactory labor. The general farm laborers consist largely of Italians, Poles, Hungarians, and Austrians. The wages range from $20 to $35 a month with board. During harvesting seasons day laborers are secured from the cities. In 1899, $811,430 was expended for farm labor, and in 1909, $1,092,116.

Although somewhat better conditions prevail in some sections than in others, the farms of Orange County are, in general, well improved. In many cases the farms are owned by residents of the cities who use them for summer homes. Other owners operate the farms on a business basis with varying results. The land is generally in demand, and much of that sold in recent years has been purchased by city residents at a price above its agricultural value. For the most part, the farm buildings and fences are kept in good condition, and the farms have a generally prosperous appearance. The total number of farms in the county reported in 1910 is 3,935. The average size is given as 97.6 acres, of which 67.7 acres are improved. The total value of all farm property is reported as $35,516,309.

SOILS

A comparatively large number of soils are mapped in Orange County, 40 distinct types or classifications having been recognized. These comprise several series which include two or more types each, besides a number of miscellaneous types. The separations are based upon the mode of formation, influence of the underlying rock upon the glacial till from which the soils are derived, and the texture of the soil material.

The soils may be divided as to manner of formation into (1) glacial-residual, (2) reworked glacial (old alluvial), (3) recent alluvial, (4) cumulose, and (5) cumulo-alluvial soils.

The glacial-residual group includes all of the soils formed by glacial action or by combined glacial and residual forces, as is the

case where the country rock is covered by only a shallow mantle of glacial drift or, as in some extreme cases, is practically bare of glacial deposit and the soil is affected markedly by materials from the underlying rock. This group is represented by the Gloucester, Dover, Dutchess, and Culvers soils.

The reworked glacial division is represented by the water-worked and water-deposited materials found in the high lake and stream terraces and kame formations. The soils in this class comprise the Hudson, Hoosic, Fox, Merrimac, Chenango, and Otisville series.

The recent alluvial soils are found in the present stream bottoms and are generally added to by successive floods. They are included in the Genesee, Clyde, and Basher series. The cumulose soils are those formed in depressions and poorly drained areas where an excessive growth of vegetation has decayed, forming muck. The term cumulo-alluvial refers to those soils along the Wallkill River composed in part of muck or decayed organic matter mixed with the silty and clayey alluvial deposit from the streams. These soils are mapped as Wallkill.

The soils of Orange County are further divided according to the origin of the soil material—or the underlying rock formation—from which they were derived. Each soil series represents a group of soils of the same origin and mode of formation; each type represents a separation based on the texture, structure, color, organic content, and other important features.

As a whole, all of the soil material of Orange County has been affected more or less by glaciation. The extent to which it has been subjected to glacial action varies widely. In some places the deposits of glacial drift are several hundred feet in depth, while on the higher elevations glacial action has been very feeble. Where the glaciation has been slight the soil is influenced by the underlying rock; but where the deposit is deep, little if any effect is shown from the underlying material. Deep glaciation is marked generally by a more or less regular topography of fairly smooth hills and ridges, which frequently have a drumlinoid shape. Sometimes these ridges and hills have a rock core, though generally those of smoother surface are composed entirely of unstratified, unassorted glacial drift. This material is of all grades, from the finest clay to large bowlders, crushed together in a heterogeneous mass.

The direction of the glacial movement has been northeast-southwest, along the longer axis of the underlying rocks. It resulted in little intermingling of materials from the different formations over which it passed, and a predominance of the fragmental rock on each separate formation is the same as the bedrock beneath, marking the separation of series quite definitely.

Geologically, the rock formations from which the soils have been derived range from those of the earliest pre-Cambrian through those of the Cambrian, Silurian, and Devonian ages.

The pre-Cambrian formation occurs mainly in the southeastern part of the county. It consists largely of granite, gneiss, and schist. It occupies parts of Cornwall, Highland, Blooming Grove, Woodbury, Monroe, Tuxedo, Chester, and Warwick Towns. The topography is rough and mountainous. Glacial action has been slight, and the soil mantle is thin and broken. Because of the extremely rocky condition, it is mapped mainly as Rough stony land and Rock outcrop. Where areas of soil are found of sufficient size and depth to be separated as a soil type, they are recognized as the Gloucester stony loam. In the extreme southern part of the formation south of the town of Warwick the less stony areas are mapped as Gloucester loam. The greater part of this land is nonagricultural and is in forest, for which it is best suited. In the stream valleys where terraces have been formed the material is largely granitic or quartzose gravel; this is mapped as the Merrimac gravelly loam.

Limestones, occurring in various parts of the county, are of the Wappinger, Neelytown, Helderberg, and other formations. South of Mount Adam and Mount Eve, in the vicinity of Amity, a large area of crystalline limestone is encountered. The soils derived from these various limestones are generally ridgy to hilly in topography, and usually quite stony and rough, with numerous ledges outcropping. In texture the soil is generally a silt loam. It is very desirable for cropping where not too stony. A small area south of Amity is of more loamy character and, being stony, it is mapped as a stony loam. All of the soils overlying the limestone and showing decided influence by the underlying rocks are mapped as Dover soils; those terraces containing a large amount of limestone material are mapped as the Fox.

The greater part of the county represents the Hudson River formation, of Silurian age. This formation occurs to the west and north of the Highland portion of the county and to the east of the Shawangunk Mountains. The region is rather broken by ridges of limestone, granite, and some Medina and Oneida shales and sandstones, but the Hudson River formation practically covers the part of the county known as the Newburgh-Wallkill Valley. This formation consists of shales, slates, etc., the strata of which dip at various angles to the surface. They often show partial metamorphosis and are warped and bent into many shapes. The predominance of the slates, or grits, determines to a great extent the character of the resulting soil. The soils derived from the Hudson River formation are the Dutchess. The more deeply glaciated material forms the stony loam

and silt loam types, which are largely derived from the more gritty material. The least glaciated of the Dutchess soils is the shale loam. This is found where the deposit of material is shallow and to a large extent of residual origin. Some areas of this soil are quite free from large fragments of rocks, while others have a large content of slabs and irregular pieces of shale. The soil on this type as a whole is shallow and not well suited to general farming.

The most important type of this series is the silt loam. The topography is usually regular and characterized by rather broad valleys. In the shallower areas it is affected more or less by the underlying rocks, but in general it is a good soil and retains moisture well.

The rocks of the Silurian and Devonian age—the Medina and Oneida and the Catskill formations—give rise to the Culvers series. East of the Shawangunk Mountains this soil is characterized by numerous rocks of Shawangunk conglomerate and sandstone in which many quartz pebbles are imbedded. These loose rocks have been transported from the mountains on the north and in some cases the soils overlie the Hudson River formation, though not perceptibly affected by the latter. West of the Shawangunk Mountains the only area marked to any extent by the conglomerate is along the Neversink River and Basher Kill. West of that the characteristic rocks are from the Catskill group and consist mainly of the gray and brown sandstones of the Medina and Oneida, with occasional areas of the red Medina, although the latter occurrence is rarely sufficient to influence the soil.

There are also extensive areas of "blue flag" and occasional outcrops of Ithaca shales. The larger part of the western section is an eroded plateau. The streams form rather narrow, steep valleys and the surface is rough and stony. This area of uplands is principally Rough stony land, Culvers stony loam, and Culvers stony sandy loam. The soil mantle is not deep and its rocky nature renders it unfit for agricultural purposes. The region is nearly all forested and a large part of it is best kept in timber.

To recapitulate the derivation of the glacial-residual group: The soils derived from the crystalline rocks are included in the Gloucester series, those from the various limestones in the Dover, those from the Hudson River slates and shales in the Dutchess, and those from the conglomerates and sandstones in the Culvers series. These represent the unmodified glacial drift, except as it may be affected by the underlying rock on which it rests.

The reworked glacial material is classified according to the rock material of which it is composed, and the depth of water at the time of deposition. It includes all of the glacial terrace soils, both

lake and stream. The material formed and deposited during later periods is either recent alluvial, cumulose, or cumulo-alluvial.

Of the glacial terrace soils, the Hudson probably represents the oldest. It is found in deep deposits, principally in the vicinity of Newburgh and Cornwall-on-the-Hudson, and along the Moodna and Woodbury Creek valleys. These are the deepest terraces of the county and contain the greatest variety of rock material. This indicates that the materials forming the Hudson series are drawn from a much wider range than any other of the terrace series. The variability in texture, or size of individual particles, also shows that it has been affected by a greater difference in currents than other series of like formation. It varies from the coarsest gravel to the fine sand and silt. It was no doubt deposited in a glacial lake, probably at the time of the impounding of the water on the south as the ice retreated. Unlike other series of the terrace deposits, it does not seem to be derived from any definite geological formation or upland soil.

The most important terrace soils areally and agriculturally are the Hoosic. These represent glacial lake and stream terrace deposits and are derived from the glaciated material of the Hudson River shales and slates. The coarser material is marked by slaty and shaly gravel and sands. The Hoosic series is represented in Orange County by four types, the gravelly loam, gravelly sandy loam, fine sandy loam, and silt loam. From its source of material or origin it is readily seen to be closely associated with the Dutchess series of glacial-residual formation.

The Fox gravelly loam, another high terrace soil, is closely associated with the Dover soils and is characterized by a high limestone content. This type is not extensive, but is very distinct in its occurrence.

Another clearly marked glacial lake and stream terrace soil is the Merrimac gravelly loam. This occurs largely in the Ramapo River and Greenwood Lake valleys. It is derived from glaciated crystalline rock material and is characterized by fragments of granite and quartz gravel. It is closely associated with the Gloucester series.

The most complete series of high terrace soils is the Chenango. It occurs only west of the Shawangunk Mountains, and is distinguished by its peculiar reddish tinge. The Chenango soils are derived from the Medina and Catskill formations and have been reworked and redeposited since glacial action occurred. The gravelly loam, gravelly sand, fine sand, sand, fine sandy loam, very fine sandy loam, and silt loam types are mapped.

The kame moraine deposits also consist of reworked glacial material. They occur as hills, ridges, and kettles of kame formation.

The soils are mapped as the Otisville. This series is characterized by numerous quartz pebbles and sands, and by the many shale fragments encountered in the soil section. Two types of this series are mapped, the gravelly loam and gravelly sandy loam.

The recent alluvial deposits occur in the stream valleys and in depressions where material from the surrounding uplands has been washed down and deposited in its present position. Some of these depressions are the bottoms of old glacial lakes. They are generally small, and the soil seems to result mainly from the deposition of material washed from the uplands rather than from purely stream action.

Areas occur along the streams that are formed almost wholly by stream deposition during periods of flood. The Genesee silt loam and the Basher silt loam are the soils most clearly formed in this manner. The latter has only a local development and is confined to the flood plain of Basher Kill. Its peculiar color is due no doubt to its source of material and to the drainage conditions.

The soils that are less clearly stream deposited are the Clyde silt loam and silty clay loam. These types have the appearance of having been laid down under lake conditions, though they have been more or less modified by stream action.

Of soils of cumulose formation, only one type is mapped, Muck. Muck represents the accumulation and deposition of decayed organic matter. It occurs in poorly drained areas where conditions have favored the extensive growth of plants. The material is many feet in depth. Muck areas occur most extensively in the "drowned lands" of the Wallkill and constitute the most valuable soil of the county.

A few miscellaneous soil types or classifications are mapped. Meadow consists of wet areas that are generally rocky and of low agricultural value and in which the material can not be satisfactorily classified into soil types. Rough stony land is the least valuable of possible agricultural land. It is too rough and stony to be cultivated and is even in some cases too rough for pasture. It is best adapted to forestry.

Rock outcrop is entirely nonagricultural and is often sheer rock. Madeland, as the term implies, comprises land which has been transported to its present position by artificial means.

These various soil types and classifications are discussed in greater detail with respect to color, depth, structure, location, and general agricultural value in the following pages. In the accompanying map the location and extent of the various soils are shown by colors and symbols.

The name and actual and relative extent of each soil type mapped are given in the following table:

Areas of different soils

Soil	Acres	Per cent	Soil	Acres	Per cent
Dutchess silt loam	130,688	24.5	Wallkill silty clay loam	1,792	0.3
Dutchess stony loam	104,128	19.5	Hoosic gravelly sandy loam	1,664	.3
Rough stony land	71,552	13.4	Chenango fine sand	1,216	.2
Muck	28,800	5.4	Chenango sand	1,152	.2
Dutchess shale loam	23,936	4.5	Chenango fine sandy loam	1,088	.2
Gloucester stony loam	23,040	4.3	Chenango silt loam	1,088	.2
Clyde silt loam	21,504	4.0	Merrimac gravelly loam	896	.2
Culvers stony sandy loam	21,120	3.9	Otisville gravelly sandy loam	832	.2
Rock outcrop	20,480	3.8	Dover stony loam	768	.1
Dover silt loam	13,120	2.5	Hudson silt loam	704	.1
Culvers stony loam	10,688	2.0	Basher silt loam	704	.1
Meadow	10,112	1.9	Hudson fine sandy loam	512	.1
Hoosic gravelly loam	9,856	1.8	Madeland	448	.1
Hoosic silt loam	6,464	1.2	Chenango very fine sandy loam	384	.1
Culvers loam	5,888	1.1	Gloucester loam	384	.1
Otisville gravelly loam	4,288	.8	Chenango gravelly sand	384	.1
Genesee silt loam	4,288	.8	Hudson gravelly sandy loam	256	.1
Clyde silty clay loam	2,944	.6	Fox gravelly loam	128	.1
Wallkill silt loam	2,368	.4	Hoosic fine sandy loam	64	.1
Chenango gravelly loam	2,176	.4			
Hudson gravelly loam	1,856	.3	Total	533,760	

BLACK SOILS

WATER-LAID MATERIAL—MIXED DERIVATION

Clyde Series

The Clyde soils are prevailingly black in the surface section, but vary to dark gray or dark brown, the strength of color being related to the quantity of organic matter present. The subsoils are gray, yellowish gray, and mottled gray and yellow, and are usually heavier than the soils. The Clyde types occur in flat or depressed, poorly drained areas, distributed throughout the northeastern quarter of the United States. They are derived from materials of mixed origin; either water-laid deposits in lakes or ice-laid deposits that have been subjected to conditions of deficient drainage.

CLYDE SILT LOAM

The surface soil of the Clyde silt loam in Orange County has the range in color typical of the series, and varies in depth from 6 to 10 inches. The subsoil is a silt loam. It is yellow and mottled with gray, the mottling increasing with depth until at 30 to 36 inches the

gray color usually predominates. Although the type as encountered in this county is fairly uniform in characteristics, it is subject to a few local variations. In wet areas the soil is darker than where better drained. While the upper subsoil is generally yellow, in places the gray color predominates. In some areas the lower subsoil at 24 to 30 inches is a silty very fine sand or a heavy very fine sandy loam.

The Clyde silt loam occurs in all parts of the county, with the exception of the section west of the Shawangunk Mountains. It is not developed in large single areas, but is widely distributed along nearly all of the stream courses, about the heads of streams, and throughout low-lying semiswampy depressions. The surface is usually flat, or only gently sloping. The type often adjoins areas of Muck.

The drainage of the Clyde silt loam is very poor. Owing to its position along the streams and in low depressions, it receives much water from the overflow of the various streams, together with the seepage from the surrounding uplands.

The type is composed of sediments deposited in old glacial lakes or by the streams during periods of flood or washed down the slopes of the surrounding uplands.[1] In some places all of these agencies have been active in the formation of the type. Glacial action is manifested in many areas by the presence of rounded glacial bowlders of foreign origin which, in places, interfere with cultivation.

The native vegetation includes elm, soft maple, linden, and beech, with some oak and hickory, and shrubs and water-loving plants and grasses.

The type is mainly in grass, either for pasture or for hay. Its best use is for grass until after it has been thoroughly drained, when it may be successfully utilized for corn, root crops, etc. Its general wet condition makes it very desirable for grass, especially for pasture. Even during dry periods the type is sufficiently moist to furnish abundant pasture when the surrounding uplands are suffering from the effects of drought. It remains wet quite late in the spring, so that early pasturing is not practicable. Where not too stony this soil produces excellent crops of hay, mainly timothy.

In many areas artificial drains have been installed, with the result that good crops of corn, yielding from 40 to 60 bushels per acre, are produced. Hay yields from 1½ to 2 tons per acre. Some root crops, such as carrots, turnips, and mangel-wurzels, are grown successfully.

No fertilizer has been used on the type and none is greatly needed. The application of lime, at the rate of 1,000 to 1,500 pounds per acre, is beneficial.

[1] The Clyde silt loam, as mapped in Orange County, includes some Papakating soil, consisting of black alluvial or stream-bottom material.

The chief value of this soil lies in its proximity to upland types, and its use in connection with these lands. The price ranges from $40 to $75 an acre, according to its condition and the character of the surrounding soil.

CLYDE SILTY CLAY LOAM

The surface soil of the Clyde silty clay loam has the typical color range of the series. It averages about 8 inches in depth, and varies in texture from a heavy silt loam to silty clay loam. The subsoil is a mottled gray and yellow or drab and yellow silty clay loam to silty clay. In places the subsoil is brownish gray or bluish gray, only slightly mottled with yellow or brown. The structure, particularly that of the subsoil, is compact, owing to the high content of clay and the generally wet condition of the type. Although difficult to cultivate in its present condition, the type where properly drained is a fairly friable soil.

This type is widely distributed throughout that part of the county east of the Shawangunk Mountains. The areas are somewhat smaller than those of the Clyde silt loam, but have the same flat or depressed topography. The soil retains moisture longer than the silt loam, and is more in need of drainage.

The type occupies low-lying semiswampy areas, lowland bordering lakes, and areas along the courses and at the heads of streams. Many of these areas are the beds of old glacial lakes, and the soil consists of sediment deposited in them. In places, however, the soil is composed of sediment washed from the surrounding uplands into basinlike depressions, while in areas along the streams the soil was formed by both the washing in of sediments from the upland, the deposition of materials in old glacial lakes, and by the addition of some sediment from the flooding streams.[1] The areas along the streams are generally narrow. The type in places is very stony. The stones are granitic bowlders brought in by the glaciers.

The native vegetation is practically the same as on the silt loam, consisting largely of soft maple, elm, linden, and beech, with shrubs and water-loving plants and grasses.

Owing to the poor drainage of this soil, the cultivation of such crops as corn, etc., is not successful. The type is best adapted to grass for pasture and hay. Some of the areas are too wet for mowing, and are only suitable for pasture during dry seasons. The supply of water is plentiful throughout the year, and the pastures are excellent throughout even the severest droughts. Where drains have been installed good yields of corn and other crops are obtained. The agricultural conditions on this soil, as a whole, are not very good. Its

[1] Some Papakating soil is included with the Clyde silty clay loam, as mapped in Orange County.

wet condition, the occurrence of floods in the spring and during periods of heavy rainfall, and the presence of stones in local areas make it generally undesirable as farm land, except in connection with the upland types. It is subject to great improvement by thorough drainage and the liberal use of lime. Where dairying is carried on with sufficient upland for the production of feed crops, the Clyde silty clay loam is best utilized as pasture land. It ranges in value from $30 to $40 an acre.

WALLKILL SERIES

The surface soils of the Wallkill series range in color from black or dark brown to gray or yellow. The subsoils consist of a dark-brown or black mucky and peaty accumulation of organic matter, often interstratified with the soil material and extending to a depth of 3 feet or more. The Wallkill types occupy low, flat, poorly drained areas in the beds of old glacial lakes or ponds, or along some of the more sluggish streams where alluvial sediments have been deposited over muck and peat. In places the deposition of alluvial material is still in progress.

WALLKILL SILT LOAM

The surface soil of the Wallkill silt loam is a black or dark-gray silt loam, mucky in places and varying from 6 to 18 inches in depth. The subsoil is a black mucky silt loam, underlain at about 30 inches by a black muck or a brown peaty muck. The soil is grayish when dry and, occurring in connection with the muck deposits, it is locally known as "gray muck." In some small areas the subsoil is yellowish.

This type is not extensive in Orange County. It occurs along the Wallkill River in the "drowned lands," and is frequently flooded.

The native vegetation consists of elm, soft maple, and willow as the principal trees, with many varieties of water-loving shrubs and grasses, nettles, and "horseweeds." Much of this soil has never been cultivated, being used for pasture and the production of hay. Where drained, onions, potatoes, carrots, and corn are grown successfully. Onions are the most important crop and yield from 100 to 150 sacks of 140 pounds each per acre. Potatoes yield from 100 to 150 bushels, hay 1 to 2 tons, and corn 30 to 50 bushels per acre. Owing to its silty character the soil is not especially adapted to the production of onions, and the crop on drained land is likely to suffer from drought unless carefully cultivated. The type, however, is well suited to corn and hay.

In the improvement of this soil, the most essential factors are drainage and protection from floods. Diking is necessary along the streams to prevent overflow, and drains are needed to carry off excess moisture.

The soil requires frequent shallow cultivation during the growing season. When not carefully tilled there is a tendency toward the formation of large surface cracks, especially during periods of drought. These cracks facilitate the evaporation of soil moisture, and often seriously hinder crop growth.

The agricultural conditions over drained areas of this soil are usually good. The value of land ranges from $40 to $75 an acre.

WALLKILL SILTY CLAY LOAM

The Wallkill silty clay loam to a depth of 6 or 8 inches has the predominating color of the series, and consists of a mucky silt loam high in organic matter. The subsoil to about 24 inches is a silty clay of brownish-gray color. Below this it consists of a dark-brown to black mucky silty clay loam. In some cases the lower subsoil is a fine, black or dark-brown muck. Where properly drained the soil is quite friable and easily tilled. The type is high in organic matter, which imparts to the soil its friable structure and dark color.

This type is not extensively developed in Orange County. It is associated with the silt loam along the flood plains and "backwater" areas of the Wallkill River. It occurs as flood plain deposits and as slight deltas where tributary streams enter the Wallkill River, in the "drowned lands" section.

The native growth is practically the same as that on the silt loam, including elm, maple, shrubs, willow, and water-loving grasses.

This soil is too heavy for the successful production of onions, but makes excellent corn and hay land when properly drained and cultivated. Since a large part of it is too wet for cultivation, large areas are devoted to the native grasses for hay.

For the improvement of this type, the same treatment is necessary as in the case of the silt loam. The main requirements are protection from floods by straightening the river channel and the construction of dikes, drainage either by open drains or tiles, and proper cultivation under favorable moisture conditions. The Wallkill silty clay loam puddles easily if worked when too wet, subsequently baking and forming clods.

This soil is usually held in connection with upland soil, and is valued chiefly as hay and pasture land.

BROWN SOILS

ICE-LAID MATERIAL—SHALE AND SANDSTONE

CULVERS SERIES

The surface soils of the Culvers series are predominantly brown. The subsoils are yellowish brown, with a peculiar reddish cast.

These soils are encountered in the northeastern part of the United States. They are derived mainly from the intermixing, under glacial action, of material from the Medina sandstone and Shawangunk conglomerate, the material having been deposited in part over the Hudson River shales. The soils are only slightly influenced by the shale. The topography varies from rolling to slightly hilly.

CULVERS STONY LOAM

The soil of the Culvers stony loam ranges from loam to silty loam in texture, from brown to dark brown in color, and is 4 to 6 inches in depth. The color of the subsoil is yellowish brown, becoming lighter at about 36 inches. Rock fragments of sandstone and conglomerate are encountered in large quantities on the surface and throughout the soil section, making cultivation of the type difficult.

This type occurs in the vicinity of Hopewell in the town of Crawford along Shawangunk Kill, extending south along the Shawangunk Mountains, and in the high upland west of Neversink River. It occupies rolling to semimountainous uplands, and much of it is unfit for cultivation because of its rough topography. The natural surface drainage is good, though in the more nearly level tracts internal drainage is poor.

The greater part of this soil is forested, chiefly with second-growth chestnut, oak, and pine. The cultivated areas are devoted mainly to dairying and the growing of grass for pasture and hay. Some corn, oats, and rye are grown. Small orchards of apples and pears are found on this type, and while not well cared for these do very well.

Much of this soil is suitable only for forestry. Where the topography is favorable and the rock content is not too great, the type makes good mowing and pasture land, and is well adapted to sheep raising and dairying.

The agricultural conditions over the Culvers stony loam are only fair. Corn yields from 20 to 30 bushels, hay one-half to 1 ton, and potatoes 50 to 70 bushels per acre. The value of land of this type of soil ranges from $20 to $30 an acre.

CULVERS STONY SANDY LOAM

The soil of the Culvers stony sandy loam consists of brown sandy loam from 5 to 8 inches deep. In some areas the color becomes a lighter yellowish brown, and the texture also varies somewhat, here and there approximating a loam. The subsoil is yellowish-brown sandy loam, the color being deeper than that of the soil. Numerous rock fragments, varying in size from a few inches to 1 or 2 feet in diameter, and consisting largely of gray sandstone, are scattered on

the surface and throughout the soil section. When cleared of timber and the surface stones the type can be cultivated, but tillage is difficult. This soil, however, is more easily tilled than the Culvers stony loam.

The Culvers stony sandy loam occurs only in the western part of Orange County. It is encountered on the western slopes of the Shawangunk Mountains and on the Catskill Plateau west of the Neversink River.

The topography is rolling to steep and broken, and in places numerous rock outcrops are found. Natural drainage is good, except in those areas near the base of the slopes, which receive the surface and seepage water from the surrounding uplands and are sometimes quite wet.

Only a small part of the Culvers stony sandy loam is cleared. The uncleared areas support a second growth of pine, oak, and chestnut. Along the western boundary of the county, bordering the Mongaup River, some of the original forest growth, mainly of chestnut and hemlock, remains.

Small patches of land have been cleared of timber and stone and are used for hay, pasture, and some corn. Apples in small orchards do well, and when sprayed and cultivated yield good crops of excellent fruit. This soil type is best adapted to forestry.

The agricultural conditions are poor and the land values low.

CULVERS LOAM

The soil of the Culvers loam is similar in texture and structure to that of the stony loam. It consists of a brown to dark-brown loam, 6 to 8 inches deep, underlain by a yellowish-brown loam to silty loam. The main differences between the two types are the more uniform topography and decidedly lower stone content of the loam. Cultivation of this type is easier than of the stony loam.

The type is developed in small areas, closely associated with areas of the stony loam having a more gentle topography.

The same crops are grown on this soil as on the stony loam, but the agricultural conditions are better, and land values are slightly higher.

DUTCHESS SERIES

The prevailing color of the Dutchess soils is brown. The subsoils are bluish, light brown, yellowish, or reddish yellow. The surface soils are friable and somewhat lighter than the subsoils. The series is encountered in the northeastern United States. The soil material is of glacial origin and derived from the Hudson River shales, slates, and sandstones. The topography is rolling to undulating or rough, much of the area consisting of rounded drumloidal hills. The drainage ranges from good to fair.

DUTCHESS SILT LOAM

The surface soil of the Dutchess silt loam ranges in color from light brown to a deep or yellowish-brown or grayish color and in texture from a true silt loam to a silty loam or in places to loam. It is about 6 to 8 inches in depth. The subsoil is a brownish-yellow to pale-yellow silty loam, varying to grayish or pale yellow mottled with gray in the lower part of the section, where it changes to a loam in texture. The line of separation between the soil and subsoil is fairly distinct. Both soil and subsoil contain large quantities of angular and subangular shale fragments, and in places the subsoil carries considerable quantities of sand and fine gravel.

Although the type is generally uniform, there is some slight variation in both color and texture. In some areas the soil is darker and more loamy than in others. In places the subsoil is comparatively compact, being known locally as "hardpan." The soil material is sometimes sandy and friable. In general, the type is easily tilled, though where it is heaviest it is considered a cold, wet land.

The Dutchess silt loam is by far the most extensive soil type in Orange County. It is distributed throughout the county between the Highlands and the Shawangunk Mountains. It generally occurs in large areas, and is best developed through a strip extending across the county from north to south in the vicinity of Walden, Montgomery, Goshen, and Warwick, and over the high ridges and hills across the Wallkill Valley.

The topography of the Dutchess silt loam is that characteristic of the series, as stated in the series description, and the natural surface drainage is good, though some of the more level tracts and low depressions between the hills require artificial drainage. The internal drainage is poor, owing to the compact nature of the soil material.

Although some foreign material is found in this soil, it is derived mainly from the underlying rock. As a whole the glacial drift composing this type is deeper than that forming the stony loam, and varies less widely in depth. Rock fragments are scattered over the surface of much of the type. Some areas, particularly in the vicinity of Walden, have the appearance of having been slightly reworked by water, possibly under lake conditions, and the rock fragments in such places are less numerous than usual. In most of the farms on the Dutchess silt loam the stones have been removed from the surface and used in the construction of fences.

The native vegetation includes chestnut, pine, hemlock, oak, elm, hickory, beech, and maple. The forest growth is mainly a somewhat patchy second growth. Some of the steeper areas are best adapted to forestry.

The greater part of the Dutchess silt loam in Orange County is cleared and under cultivation, and it is the most valuable general farming type in the county. It is well adapted to a wide variety of farm crops, but is generally devoted to dairying, little attention being given to any crop other than hay, with corn for ensilage or fodder. The main hay crop is timothy and redtop. Fields are kept in sod for 8 or 10 years. The yield of hay ranges from three-fourths to $1\frac{1}{2}$ tons per acre. Clover and alfalfa are also grown successfully with proper care and management, including thorough drainage, the preparation of a good seed bed, and the application of lime. Some corn is grown for grain, but much of the corn and other grain used for feed is shipped into the county. Oats and rye are the principal small grains grown. These give fair yields. Buckwheat is also a crop of some importance. From 100 to 150 bushels of potatoes per acre are obtained on well-drained areas with proper fertilization and cultivation. The type is also used for the production of apples, pears, peaches, cherries, and small fruits. The Baldwin, Greening, Spy, and King are the leading varieties of apples grown.

The agricultural conditions as a whole are good, as is indicated by the general appearance of the farms, fences, and buildings. There is a general need, however, of greater diversification of crops, better drainage, more thorough methods of cultivation, and the rational use of fertilizers and lime. Best results are secured where feed for stock is produced at home and where a systematic rotation of crops, in which legumes have a prominent part, is followed. The most successful farmers make a study of the adaptation of crops to the existing soil conditions, and grow alfalfa and clover where the conditions are at all suitable. Sheep raising and hay production offer excellent opportunities.

The value of this type varies considerably according to the location and condition of the land, the improvements upon it, and the use to be made of it. In general, the farms range from $75 to $150 an acre. Some of the well-developed farms have a much higher value.

DUTCHESS STONY LOAM

The soil of the Dutchess stony loam consists of a brown, grayish-brown, or yellowish-brown loam or silty loam, varying in depth from 4 to 8 inches. Beneath this to a depth of 18 inches the color and texture change, the former becoming yellower and the latter somewhat more silty than the surface soil. From 18 to 36 inches the material is a brown loam mottled with yellow. Both soil and subsoil contain many angular and glacially rounded rock fragments. These, while not large, are frequently present in sufficient quantities to preclude cultivation. The larger fragments have been removed

and used in buildings, fences, and road construction. The rock is usually shale and slate, thin-bedded sandstone from the underlying strata, and rounded glacial gravel and bowlders of granite and quartzite of foreign origin. Frequent outcrops and ledges of the underlying formations add to the difficulty of cultivation.

The Dutchess stony loam is one of the most extensive types of the county. It is distributed throughout the great central valley which lies west of the Highlands and the Hudson River. It is encountered on the northwestern slopes of the Highlands and the Schunemunk Mountains and on the eastern slopes of the Shawangunk Mountains. The type is not found west of the Shawangunk range or in the roughest part of the Highlands. It is fairly well developed from Newburgh north to the Ulster County line. Some of this area is quite rough and broken. This rougher portion consists of the southern end of Marlboro Mountain, which extends from southeastern Ulster into the northeastern section of Orange County. The largest development of the type is west of the Wallkill River. This area is broken by areas of the Dutchess silt loam and shale loam, Meadow, Muck, and various other types.

The topography of the Dutchess stony loam varies widely, ranging from nearly level to very rugged and steep. As a rule the surface is very uneven, and is marked by numerous rounded ridges and hills. These sometimes have elevations above the surrounding country of 100 to 200 feet or even more in the rougher and steeper sections. The outcrops of rock from the underlying strata are most common on the higher elevations. The lower situations resemble drumlin formations, comprising relatively low, broad hills or ridges. As a whole the topography is distinct and characteristic of this soil type. The topographic features are such that natural surface drainage is generally good to excellent. However, the character of the soil material, where of considerable depth, is such that artificial drains of either tile or stone are beneficial, even on the steep slopes. At the base of the slopes where the surface is more nearly level, and between the many ridges there are tracts that receive the excess surface drainage and seepage from the higher areas. These tracts are often much too wet for cultivation, and can be permanently improved only by artificial drainage. The many creeks and brooks which traverse this soil afford good outlets for the drainage water.

This soil contains very little foreign material. The degree to which glaciation has taken place varies widely, but the resulting soil material does not seem to have been moved any great distance. The glacial drift or débris varies in depth from a few inches on the highest hills to 500 feet or more in the deepest deposits. This material is unstratified and unassorted, ranging in texture from the

finest bowlder clay to sand and from fine gravel to bowlders weighing many tons. In the deepest deposits, such as the large, rounded drumlinoid hills and ridges, the bluish, compact material characteristic of glacial till is encountered. While the mechanical action of glaciers has been the chief factor in the formation of the type, ordinary weathering processes have had an important part in the formation of the material in the areas thinly glaciated.

The native vegetation consists of oak, elm, maple, chestnut, cedar, and locust. Very little of this type supports the original forest, though a considerable area is in second growth.

The Dutchess stony loam is generally used for dairying and is largely kept in grass and pasture. It is well adapted to this industry. The type constitutes a good general farming soil where not too rough and stony. Hay yields from one-half to 1½ tons per acre, corn 40 to 50 bushels, oats 20 to 30 bushels, rye 15 to 20 bushels, buckwheat 10 to 15 bushels, and potatoes 50 to 100 bushels per acre. The rougher areas are utilized for pasture and the more level and less stony areas for the growing of corn for ensilage and grain. The greater part of the grain used for feeding purposes is shipped into the county. Sheep raising offers excellent opportunities on this type. Those areas which are too rough for grazing cattle might be used for sheep pasture.

Fruit growing is an industry to which this soil seems exceptionally well suited. This industry is most highly developed in the northeastern part of the county between Newburgh and the Ulster County line. Apples, pears, peaches, plums, and cherries are successfully grown and the increasing acreage devoted to these fruits indicates that their production is profitable. Strawberries, blackberries, raspberries, currants, and gooseberries also are grown successfully. These find ready markets in the local towns and in New York and Boston. Outside of this fruit section there are many farm orchards and a few market orchards in other sections on this type.

Agricultural conditions are fair to good. Land values range from $30 to $50 or more an acre, depending on the condition of the soil, the improvements, and location.

DUTCHESS SHALE LOAM

The Dutchess shale loam consists of a brown to light-brown loam 4 or 5 inches in depth, underlain by a yellowish-brown material of the same texture. Shale fragments are mingled with this fine earth in both soil and subsoil, and where the subsoil is deepest it is often a mass of shale fragments, with very little interstitial material, below 30 inches. The fine material, as a whole, is very silty and approaches a silt loam. There is little difference between the deepest phases of

the shale loam and the shallowest phases of the silt loam of the Dutchess series, the principal difference being the greater quantities of shale fragments and the corresponding lack of foreign material in the shale loam. In some areas the type is plastic, and in others it is somewhat gritty.

The rock fragments found in the soil mass and scattered over the surface vary greatly in size, ranging from small chips to large, slabby blocks. In some areas they merely give the soil a gravelly nature, while in others they are present in such large quantities as to prevent tillage. In many places the larger rocks have been removed from the fields and used for building fences or roads. Very few rounded gravel or stones of foreign origin are found in this soil.

The Dutchess shale loam is widely distributed throughout the great central valley between the Highlands on the east and the Shawangunk Mountains on the west. Extensive areas are located in the vicinity of Maybrook and north of Unionville. Other large areas occur in the towns of Warwick, Chester, Goshen, Blooming Grove, and Hamptonburg, and along the eastern side of the Shawangunk Mountains.

The topographic features are peculiar to this soil type. They consist mainly of rounded hills, knolls, and ridges, with small intervening valleys. Many rock ledges and outcrops occur. The hills and ridges have an uneven surface and are sometimes precipitous. Surface drainage is usually good, though some of the areas between the hills are in need of draining. Owing to the general open structure of the underlying rock the internal drainage is good. The lower slopes are often wet because of seepage from the hillsides above. The soil in such places is usually deep.

The native vegetation consists largely of chestnut and oak with some pine and hardwoods.

Owing to its rock content the tillage of this soil is difficult. In some localities the underlying rock is so close to the surface that the land can not be satisfactorily plowed. The greater part of the land is in pastures or forest. In some cases it is devoted to the production of hay, but the yield is frequently low, and the crop unprofitable. The pasture and hay fields suffer for lack of moisture during periods of dry weather. Farm crops such as hay, corn, oats, rye, and buckwheat are grown, and while the quality is usually good the yields are low. Buckwheat, however, is one of the most profitable crops grown. The soil is well adapted to potatoes, where the land is not too stony and rough, and where a good supply of organic matter is maintained.

Fruit growing is carried on quite extensively on this soil, and excellent yields, particularly of peaches, are obtained. The gentler slopes seem best adapted to fruit. The bush fruits also do well.

The rougher and more stony areas are best suited to forestry, as they are too rough for cultivation, and during dry seasons the pastures fail because of lack of moisture. The agricultural conditions of this type are only fair. Land values range from $30 to $50 an acre.

OTISVILLE SERIES

The surface soils of the Otisville series are brown and the subsoils yellowish in color. The topography varies from rolling to hilly. The soils are encountered in the northeastern section of the United States. They are derived from noncalcareous kame and esker material. These soils differ from those of the Rodman series in the absence of limestone as an important constituent. Drainage is usually good.

OTISVILLE GRAVELLY LOAM

The soil of the Otisville gravelly loam is a medium-brown to yellowish-brown gravelly loam, 4 to 6 inches in depth. The subsoil is a yellow to yellowish-brown gravelly loam, grading in lower depths in some places into a gravel. The materials composing this type are loose and open and become more gravelly and sandy with increasing depth. Rounded and waterworn gravel and stones, from one-half inch to 3 or more inches in diameter, are scattered over the surface and throughout the soil section. In places sand predominates in the subsoil, while in others it is not encountered at less than 6 feet. Deep cuts show considerable stratification. Where the topography is favorable the type is easily cultivated.

This type is comparatively inextensive, and occurs mainly in the western part of the county and in the Wallkill Valley. It is developed in the vicinity of Otisville and near Bloomingburg, Crystal Run, New Hampton, Denton, Breeze Hill, between Ridgebury and Slate Hill, and near Westtown. The areas near Bloomingburg are not typical, not being uniform in occurrence or texture. The soil approaches a gravelly sand or sandy loam. This development is too inextensive, however, to be mapped separately.

The surface features comprise rounded hills, knolls, and ridges, with an occasional flat plain, and deep intervening depressions. The depressions are frequently occupied by lakes or ponds suggestive of kettle holes. The drainage is good, the internal drainage in places being excessive.

This soil is derived mainly from the Hudson River shales and Shawangunk conglomerate. Very little foreign material is encountered. The flat areas are doubtless outwash plains or deltas formed by the glacial streams.

The native growth consists largely of chestnut, pine, oak, sumac, and some shrubs.

The topography is generally unfavorable for tillage operations. In places crops suffer from drought. The type is used mainly for pasture. Where cultivated, corn, oats, rye, and grass for pasture and hay are grown. The soil is adapted to alfalfa and clover, and to fruits such as peaches, cherries, raspberries, blackberries, dewberries, strawberries, currants, and gooseberries. The sandier phases are suited to early potatoes and truck crops.

The land is usually held in connection with the upland types, and is valued at $25 to $40 an acre.

OTISVILLE GRAVELLY SANDY LOAM

The surface soil of the Otisville gravelly sandy loam is a brown to light-brown gravelly sand to gravelly sandy loam 5 to 8 inches in depth. The subsoil is a yellowish-brown to yellow gravelly sand to 24 or 30 inches. Below this depth there is usually an increase in the sand content. In places gravel and sand layers are interstratified, generally below the 3-foot section. The gravel varies from fine to coarse and is mainly quartz. There are few large stones in the soil or on the surface.

This type occurs mainly in the Wallkill Valley north of Walden, near Pellets Island, Phillipsburg, and Breeze Hill, in the Moodna Valley near Idlewild, and near Otisville. The surface comprises rounded hills, knolls, and ridges, and drainage is good to excessive.

The native growth, which is rather sparse, is practically the same as that on the gravelly loam type. The type is not important agriculturally, and very little of it is cultivated. This is largely due to the uneven topography, though the tendency to droughtiness is also a hindrance to cultivation. The type affords some pasturage.

The type is adapted to fruit and vegetables. It is an early soil, and on detached areas, peaches, cherries, grapes, all kinds of berries, and potatoes and other vegetables could be grown successfully.

Land values on this type range from $30 to $40 an acre.

ICE-LAID MATERIAL—CRYSTALLINE ROCKS

GLOUCESTER SERIES

The soils of the Gloucester series are light brown, ranging to grayish; the subsoils are yellow. Scattered rocks and large bowlders occur in places, and small quantities of mica are sometimes present. The topography ranges from gently undulating to rolling or hilly, the hills usually being high, broad, and rounded. Drainage is fair to good and in places excessive. The soils are derived from a rather local glaciation of crystalline rocks, consisting chiefly of granite and gneiss, with a small amount of schist, the material being left as a

thin mantle of ground moraine. These soils are developed in north eastern United States.

GLOUCESTER LOAM

The soil of the Gloucester loam varies from a brown loam to silty loam of friable structure and from 5 to 8 inches deep. The surface color in Orange County is darker than typical. The subsoil to a depth of 24 inches is a yellowish-brown loam. Below this depth it is reddish brown and has a higher sand content. While the subsoil is more gritty than the soil it is quite compact at 18 to 24 inches and is retentive of moisture.

This soil type is not extensively developed and occurs only in the southern part of Warwick Town, near the county line. Owing to the rolling to hilly topography surface drainage is good. The compact structure of much of the upper subsoil, however, is such that underdrainage would be beneficial.

The chief differences between this type and the Gloucester stony loam are that the latter type is generally much shallower, more stony, and of rougher topography. There is, however, a slight difference in the types as the result of a greater admixture of residual material from the underlying rock in the soil and subsoil of the stony loam.

The native vegetation consists largely of pine, oak, and chestnut, most of which is second growth.

Where cultivated, corn, oats, buckwheat, and hay are grown, though the yields are not large. Hay is the most important crop and in general the soil is well adapted to hay production. Much of the land is too steep for growing intertilled crops. Hay yields from one-half to three-fourths ton per acre, oats 25 bushels, and rye 10 to 15 bushels. Drainage, liming, and green manuring are needed to increase crop yields.

Some orchards of apples and peaches are found, and where properly cared for these give good returns.

The value of this land is comparatively low—$25 to $40 an acre.

GLOUCESTER STONY LOAM

The soil of the Gloucester stony loam consists of a stony loam to stony sandy loam, of light-brown to yellowish-brown color, varying in depth from 4 to 10 inches. The subsoil is a reddish-brown or yellowish-brown loam of relatively high sand content. Both soil and subsoil are usually friable, and where free from rocks easily cultivated.

The lower subsoil is sometimes partly residual. Both soil and subsoil frequently contain mica scales.

This soil is encountered mainly in Cornwall, Highland, Tuxedo, and Warwick Towns. Other areas are found in Monroe, Chester,

and Newburgh Towns. It is developed at the base of steep slopes, as narrow bands paralleling the narrow valleys, and on shelves of rock in the rough districts. The type is mapped in irregular areas which are usually the less rough portions of the mountains.

The topography is in general rough and broken, the surface varying from gently sloping to steep. The type is generally surrounded by areas of Rough stony land or Rock outcrop.

The drainage is good, except in those areas at the base of the Highlands, which often lack proper drainage, owing to the accumulation of seepage water. The natural surface drainage is excellent.

Where the glacial deposits are thin, the underlying rocks have influenced the soil in both color and texture. A large number of rounded bowlders of glacial origin are distributed over the surface. The stone content is generally great enough to make cultivation extremely difficult. The stones are of varying size and are generally of the same material as the underlying strata, gneiss and granite of pre-Cambrian age. Where the glacial deposits are deepest, the subsoil is often compact.

The crops to which the Gloucester stony loam is best adapted are those that require the least cultivation, such as grass for pasture or hay. Some corn is grown, and oats and buckwheat yield fairly well. Good orchards of apples, pears, and peaches are found. Grapes could probably be successfully grown. The best use for the type, however, is for pasture or hay. Some of the roughest areas are suited only to forestry.

ICE-LAID MATERIAL—LIMESTONE

DOVER SERIES

The Dover series includes types with light-brown or dark-brown to reddish soils, and light-brown to yellowish or reddish subsoils. Limestone fragments are scattered over the surface and throughout the soil and subsoil. These soils occur in those limestone lowland belts of the Appalachian region which have been subjected to glaciation. The topography is undulating to hilly, and drainage is good. Outcrops of limestone are common. The soils are derived from glacial till material which has been considerably modified by the admixture of local limestone material.

DOVER SILT LOAM

The soil of the Dover silt loam consists of 6 to 8 inches of brown to yellowish-brown, friable silt loam. The subsoil is a light-brown silt loam somewhat heavier than the surface soil.

The thickness of the drift material from which this soil is derived varies greatly. It is generally much more than 3 feet, and ranges

to perhaps 100 feet or more in depth. There are, however, many areas of shallow soil where the underlying limestone is within 3 feet of the surface. Where the rock approaches the surface, the subsoil is usually darker in color and is sometimes partly residual.

The Dover silt loam is not of large areal extent in Orange County, but the areas are widely scattered. It occurs wherever the various limestones lie near enough the surface to have any effect on the soil material. It is most extensively developed in Warwick Town. Scattered areas are found in Newburgh, Goshen, and Wawayanda Towns.

The topography is rolling to hilly and often quite broken. The surface drainage is good, although in the more gently sloping areas artificial drains are beneficial, especially where the subsoil is compact.

The native vegetation includes oak, chestnut, locust, cedar, and some hickory.

The Dover silt loam is locally known as "limestone land" and is considered an excellent farming soil. While some of the areas are quite suitable for cultivation, others are somewhat rough, and in these tillage is possible only in patches. The greater part of the type is cleared and cultivated. The crops most generally grown are corn, oats, rye, wheat, clover, and alfalfa. The type supports excellent orchards of apples, pears, and peaches. Corn is usually grown for silage, but where produced for grain it yields from 40 to 75 bushels per acre. Wheat yields as high as 40 bushels per acre, oats 35 to 50 bushels, and rye 15 to 30 bushels. The yield of clover and timothy hay ranges from 1 to 2 tons per acre. Alfalfa is successfully grown, especially where the soil is thoroughly drained. The Dover silt loam responds readily to good treatment and the application of barnyard manure. It is utilized largely in dairy farming, and this industry furnishes a good supply of manure, which is the principal fertilizer used. Lime has been used with success.

The value of land on this type ranges from $50 to $100 an acre.

DOVER STONY LOAM

The soil of the Dover stony loam is 8 to 10 inches in depth. The fine soil varies from a loam to silt loam in texture, and from brown to grayish brown in color. The subsoil is usually very similar to the soil, although in some areas it is heavier and has a more compact structure.

The type is inextensive. It is encountered in only a few areas, and these are mainly in Warwick Town. The topography is generally rough and broken, and the drainage is usually good.

The native vegetation, other than the grasses, is scattering, and consists largely of cedar. Some of the rough and stony areas support a thick growth of cedar.

Cultivation on the Dover stony loam is very patchy, owing to the rugged surface and the great number of rock fragments on the sur-

face and in the soil. The type is best used for pasture. Where the small, irregular areas are tilled, clover, timothy, corn, oats, and buckwheat are grown. Some orchards of peaches and apples are found.

The price of the land is comparatively low, although the value of the type for pasture land is relatively high.

WATER-LAID MATERIAL—SHALE AND SANDSTONE

CHENANGO SERIES

The soils of the Chenango series are prevailingly brown, ranging to reddish brown. The subsoils are brown to reddish brown or yellowish. The occurrence of stratified gravel and coarse sand at a depth of 3 feet or more is characteristic of the series. These soils occur in the northeastern and central States. They are developed along the streams in those sections of the glaciated region where the upland soils result from the glacial grinding of limestone, shale, and fine-grained sandstone, with an admixture of small quantities of material from areas of igneous and metamorphic rocks. The Chenango material was deposited by relatively rapidly flowing waters from the melting and receding ice masses. Upon the disappearance of the ice and the subsequent deeper erosion by less voluminous postglacial streams this material was left as terraces, which are not now subject to overflow. The Chenango soils are often associated with the Dunkirk series, of lake deposition, forming southward extensions of similar material along old glacial drainage ways.

CHENANGO SILT LOAM

The soil of the Chenango silt loam is a dark-brown silty, very fine sandy loam or silt loam, with a depth of 8 to 10 inches. The subsoil is reddish-brown silt loam in places, grading downward into a very fine sandy loam. The type is generally friable and easily tilled.

This type is inextensive in Orange County. It is encountered in the Neversink River Valley. The topography is flat to slightly rolling. The type is generally developed as a stream terrace, although occasional areas are apparently high first bottoms. The drainage is only fair, and during wet seasons much damage is caused to intertilled crops. The type is subject to overflow only by extremely high waters, and then only the low-lying tracts near the streams are affected. Artificial drainage is beneficial, especially during wet seasons.

The greater part of the Chenango silt loam is cleared and cultivated. Its principal use is for hay and pasture. Corn, potatoes, cabbage, oats, and rye are grown successfully.

The agricultural conditions on the Chenango silt loam are very good. Land values range from $60 to $100 an acre.

CHENANGO VERY FINE SANDY LOAM

The surface soil of the Chenango very fine sandy loam is a dark reddish brown very fine sandy loam, with a depth of 5 to 8 inches. The upper subsoil is similar in color and texture to the soil, but in places changes in its lower depths to a very fine sand of pinkish-gray color. The soil and subsoil are friable and good tilth can easily be maintained by proper cultivation.

The Chenango very fine sandy loam occurs in the valley of the Neversink River. The surface is level to sloping and drainage is fair to good.

All of this soil is under cultivation, being utilized for the production of general farm crops or for dairying. It produces excellent crops of corn, rye, and oats and constitutes good pasture and hay land. The type is well adapted to fruits, such as peaches, cherries, raspberries, blackberries, gooseberries, currants, and strawberries. Potatoes give excellent results.

The agricultural conditions and the character of farming are very good. The value of this land ranges from $75 to $100 an acre, depending upon the location and improvements.

CHENANGO FINE SANDY LOAM

The Chenango fine sandy loam consists of 6 to 8 inches of dark-brown, friable fine sandy loam, resting on subsoil of reddish-brown fine sandy loam, which in places is underlain at 30 inches by medium sand. Gravel occurs in places in the lower depths, and an occasional patch is found on the surface.

This type is developed as low terraces or high first bottoms, and is not subject to overflow, except during unusually high floods, when the water is backed up in the river valleys by ice jams. It occurs only in the Neversink River Valley. The topography is level to sloping, and the drainage is generally good. The Chenango fine sandy loam occurs at lower levels than the Chenango fine sand. It differs from the fine sand in that it is more loamy and has a much higher content of organic matter. It is better adapted to general farm crops, and makes excellent grass land.

The entire type is cleared and cultivated. Dairying is the principal industry. The soil gives good yields of hay, corn, oats, rye, and potatoes. Much of this soil is well suited to truck crops and small fruits.

Land of this type of soil ranges in value from $50 to $75 an acre.

CHENANGO SAND

The soil of the Chenango sand consists of a dark-brown to reddish-brown sand or light sandy loam, from 3 to 5 inches deep. The subsoil to a depth of 36 inches or more is a reddish-brown sand. The type contains some rounded pebbles, and in small, irregular areas

a considerable quantity of larger gravel and stones is encountered. The material is loose and somewhat incoherent, and very susceptible to drought.

The areas of Chenango sand are small, and are located along the Delaware, Mongaup, and Neversink Rivers. They occur as stream terraces with flat to sloping surface. The drainage is good to excessive. The terraces along the Delaware River are higher than those in the Neversink Valley and the soil is more droughty.

The native vegetation includes pine, chestnut, hemlock, and some oak.

Very little of the Chenango sand is under cultivation. This is due in part to the droughty nature of the type, the result of its loose, open structure. In its present condition, also, it is not well adapted to cultivation, because of its low organic content. Fruits of all kinds, early potatoes, and truck crops should do well on the better areas, when this deficiency has been supplied.

CHENANGO FINE SAND

The Chenango fine sand ranges from a dark-brown fine sand to a fine sandy loam, 6 or 8 inches deep, resting on a subsoil of light-brown fine sand, to 18 inches, in turn resting upon a reddish or pinkish-brown fine sand. The material has a loose, open structure, and in general is droughty. The more loamy areas, being somewhat more retentive of moisture, produce larger crops than the typical fine sand areas.

Areas of the Chenango fine sand are found in the valleys of the Delaware and Neversink Rivers, where they form stream terraces lying above overflow. The surface is level to gently sloping and the drainage is good.

Nearly all of this type has been cleared and is under cultivation, largely to general farm crops. It is an early soil and is especially adapted to truck crops, such as early potatoes, early sweet corn, asparagus, tomatoes, peppers, cabbage, peas, and beans. It is also suited to the production of strawberries and bush fruits.

No effort is made to keep the soil supplied with organic matter. This has resulted in a rather more open structure than is conducive to good crop production.

The agricultural conditions are only fair on this type and the land values range from $20 to $50 an acre.

CHENANGO GRAVELLY SAND

The Chenango gravelly sand is a dark-brown to grayish-brown gravelly sand or light loam in places and ranges to a light gravelly loam. The soil varies in depth from 6 to 8 inches. The subsoil is a gravelly sand of yellowish or reddish-brown color. The material within and below the 3-foot soil section shows decided stratification.

This type is encountered only in the Neversink River Valley, where it occurs as high terraces. There is no danger from floods, and the drainage is well established.

The agricultural conditions are poor. Some corn, rye, and hay are grown. The best results are had where a regular rotation is followed, and the organic-matter content of the soil built up.

CHENANGO GRAVELLY LOAM

The soil of the Chenango gravelly loam is a brown to dark-brown loam carrying much gravel and from 4 to 8 inches deep. This surface material is underlain by a reddish-yellow gravelly loam to a depth of 36 inches. The surface in places is thickly strewn with large, waterworn stones, often 8 to 12 inches in diameter. These areas are practically nonagricultural, unless the stones are removed from the surface. In other small areas the type is practically free of stones.

In general, the Chenango gravelly loam is friable and mellow, and a good tilth is easily maintained where the stones and gravel are not too numerous. As a rule the type is droughty.

The topography is flat to rolling, and drainage is excellent.

This type is developed west of the Shawangunk Mountains as bodies in the valleys of the Delaware and Neversink Rivers. It is also encountered in the uplands of the Catskill Plateau in the vicinity of Quarry Hill and Rio, where it occurs as a high lake terrace or as a delta plain.

The native forest consists largely of oak and chestnut. Only a small part of this type is under cultivation. The land is valued at \$20 to \$30 an acre.

HOOSIC SERIES

The Hoosic soils are predominantly brown, and the subsoils are yellow. The series, like the Chenango, is found on the high glacial terrace and delta soils of New York and western New England, but the material is derived from the mixed glacial and residual débris from crystalline and semicrystalline rocks of the region instead of largely from shale, sandstone, and limestone formations. The included gravel of the Hoosic soils consists of thin, waterworn slate and shale. The soils are gravelly and sandy, especially in their lower depths. The Hoosic soils differ from the Merrimac types, which occur as broad, flat terraces along the larger streams of New England, in that the latter are formed largely of wash from acidic rocks of more coarsely crystalline character.

HOOSIC SILT LOAM

The soil of the Hoosic silt loam, which extends to a depth of 6 or 8 inches, consists of a grayish-brown to brown, friable silt loam. The subsoil has the same texture as the soil, but varies considerably

in color. Ordinarily the color is yellow, but it may be mottled with different shades of gray. The type is friable and mellow when worked under proper moisture conditions, but it is sufficiently heavy to clod badly if plowed when wet.

The Hoosic silt loam is not an extensive type in Orange County, but occurs in somewhat widely scattered areas. The largest lie in the vicinity of Pinebush, Walden, Montgomery, and Johnson.

The topography is flat to rolling, and surface drainage is fair to poor. The compact nature of the subsoil makes artificial underdrainage necessary in many cases, and it is beneficial on most of the type.

The soil seems best adapted to the production of grass and grain crops. It makes excellent pasture land, and the mowings produce from 1 to 2 tons of hay per acre. Timothy is the principal hay grass. Corn yields from 40 to 60 bushels, oats 30 to 50 bushels, and rye from 15 to 25 bushels per acre. Potatoes yield from 75 to 150 bushels per acre. Fruit is not generally grown, although there are some orchards of apples and pears.

Agricultural conditions are generally good, and the farms are in good condition. The price of land ranges from $60 to $90 an acre.

HOOSIC FINE SANDY LOAM

The Hoosic fine sandy loam consists of 5 to 8 inches of light-brown to medium-brown fine sandy loam, underlain by a yellowish-brown fine sandy loam.

The type is of small extent. It occurs southwest and east of Pinebush. It is developed in such small areas that no definite value can be given it.

The type is generally well drained and easily tilled. It is an early soil and well suited to gardening, trucking, and to the growing of strawberries and bush fruits.

HOOSIC GRAVELLY SANDY LOAM

The surface soil of the Hoosic gravelly sandy loam consists of 6 or 8 inches of brown gravelly soil of somewhat variable texture. Typically the fine earth is a sandy loam, but areas of lighter and of heavier texture occur. The subsoil ranges from a light-brown or yellowish-brown gravelly sandy loam to gravelly sand. In the lower depths it varies from pale yellow to dark brown. As a rule, the gravel varies from medium to coarse and is scattered on the surface and throughout the soil section. Small areas occur in which the finer material has been washed out and carried away by water, leaving only the gravel. Below 36 inches the material is generally either a gravelly sand or a sandy gravel. The deeper section always shows stratification. This soil is one of the easiest in the county to cultivate.

The total area of Hoosic gravelly sandy loam is not great, although the type is widely scattered throughout the central part of the county. It occurs as irregular bodies closely associated with other types of this series.

The country occupied by the Hoosic gravelly sandy loam comprises rounded hills and knolls, ridges, rolling plains, and nearly level tracts. The surface features are such as to permit good surface drainage and the open structure of the soil is favorable to good internal drainage.

Practically all of the type is cleared and under cultivation.

It is particularly adapted to the production of fruit. Peaches, cherries, and plums do well. Orchards of apples and pears appear to be in thrifty condition. Of the small fruits, strawberries, blackberries, raspberries, gooseberries, and currants do especially well. Grapes also are grown successfully. This is an early, well-drained soil and for this reason a good truck soil. Potatoes, sweet corn, melons, cabbage, peppers, asparagus, and cucumbers are among the crops successfully produced.

Ordinary farm crops do not yield heavily because of the open nature of the soil and its low organic-matter content. The type is too droughty to make good pasture land. Rye and oats are the principal grain crops, though some corn is grown. Clover and alfalfa are successfully seeded on this soil.

Agricultural conditions and land values are about the average for the county. The soil is generally in need of organic matter.

HOOSIC GRAVELLY LOAM

The soil of the Hoosic gravelly loam consists of a light-brown to brown gravelly loam from 4 to 6 inches deep. The subsoil typically is a yellow to yellowish-brown gravelly loam, but in some areas it becomes sandier with depth to 18 or 24 inches, below which very little interstitial material is present. The soil and subsoil contain varying quantities of shale fragments, and similar material is scattered over the surface of most areas.

Areas of the Hoosic gravelly loam are scattered throughout the central part of the county, east of the Shawangunk Mountains. They occur as strips along streams and as larger, irregular-shaped areas, the largest of which lie in the town of Montgomery, near Walden and Montgomery, in Wallkill Town, near Stony Ford, and in the town of Minisink, near Westtown and Waterloo Mills. Other areas are encountered near Warwick, Monroe, Washingtonville, Middletown, and in many other places.

The topography ranges from nearly level to sloping and ridgy. Where erosion has been active the areas are rolling and even hilly. Drainage, as a rule, is excellent, though areas lying at the base of

slopes are too wet during a part of the year, owing to seepage and surface drainage from the adjacent higher lands.

The material of which this type is composed is generally stratified. This may not always be discernible in the upper part of the deposits, but it is always seen in deep sections. The strata consist of roughly assorted waterworn and rounded materials.

The native vegetation includes oak, elm, hickory, pine, and some chestnut. Practically all of the forest has been removed.

Most of this soil is farmed. It is an easy soil to cultivate, and gives good returns of the general farm crops. It is not considered an especially strong soil and does not retain moisture and fertilizers well, but its good drainage and the general ease with which it can be cultivated make it desirable. Corn, oats, and hay are the crops most generally grown. Corn yields from 40 to 50 bushels, oats 25 to 35 bushels, and hay 1 to 1½ tons per acre. Potatoes yield from 80 to 150 bushels per acre. In addition to these crops, orchard and small fruits are grown profitably.

The agricultural conditions on this type are fairly good.

WATER-LAID MATERIAL—CRYSTALLINE ROCKS

MERRIMAC SERIES

The surface soils of the Merrimac series are brown. The subsoils are predominantly yellow, and consist largely of sand and gravel. The series occurs in eastern New York and the New England States, and comprises high glacial terraces along the streams of this region. The material is derived from crystalline rocks. It was ground up by the ice, reworked by water, and deposited during the close of the glacial period.

MERRIMAC GRAVELLY LOAM

The Merrimac gravelly loam consists of about 6 inches of dark-brown to brown gravelly loam resting on a subsoil of yellowish-brown material of the same texture as the soil. The soil is friable and easily cultivated where the gravel content is not excessive.

The type is characterized by rounded rock fragments of varying sizes, ranging from fine gravel to stones 3 to 6 inches in diameter. While the greater part of the land is not too stony for cultivation, in some small areas tillage would be difficult. There are occasional areas of silty texture which, if of sufficient size, would be separated as a silt loam, although these areas contain pockets of gravel. The drainage of the type in general is good.

This Merrimac gravelly loam generally occurs as long, narrow strips, comprising flat terraces along the streams which flow through the Highland region. The most extensive areas are developed along the Ramapo River, and at the head of Greenwood Lake. Other

areas are found near Eagle Valley and Queensboro, in the southeastern part of the county.

The Merrimac gravelly loam is used in the production of corn, oats, rye, hay, and orchard crops. Corn yields as high as 40 bushels per acre, oats 30 bushels, rye 15 to 20 bushels, and hay three-fourths to 1 ton per acre. The agricultural value of the type, however, is not high, as the areas are small and occur mainly in a section that is not generally used for farming purposes. Its value ranges from $20 to $30 an acre.

WATER-LAID MATERIAL—MIXED DERIVATION

FOX SERIES

The Fox soils are brown to gray in color. The topography is level, except where varied by potholes or eroded valleys. The series occurs in northeastern United States. The material was deposited as outwash plains or as terraces along streams within the glacial area or flowing out of it. It is wholly or mainly of glacial derivation and consists largely of limestone.

FOX GRAVELLY LOAM

The surface soil of the Fox gravelly loam consists of 5 to 8 inches of brown to dark-brown gravelly loam. The subsoil to a depth of about 30 inches is a yellowish-brown gravelly loam, but below this it passes into a bed of grayish gravel. The soil and subsoil are friable and porous.

This type is not extensively developed in Orange County. It occurs in small areas in the Wallkill Valley in the vicinity of Pine Island and Liberty Corners. The topography is rolling to ridgy, and both surface and internal drainage are good.

This type is generally held in connection with other soils. It is adapted where economic conditions are favorable to the production of leguminous crops and fruits.

GENESEE SERIES

The Genesee soils range in color from dark brown to grayish brown. They occur along the major streams and their tributaries throughout the northeastern glaciated region, particularly where the Dunkirk, Volusia, Miami, and Ontario series constitute the principal upland soils. The Genesee series extends a short distance south of the glaciated area, where the main streams have their headwaters in areas of the above-named series. The material consists of alluvial sediments. These soils are subject to annual or seasonal overflow.

GENESEE SILT LOAM

The surface soil of the Genesee silt loam is 8 to 10 inches deep. In texture it is a friable silt loam and in color dark grayish brown.

The subsoil to a depth of 24 inches is a brown silt loam slightly tinged with gray. From 30 to 36 inches these mottlings are more prominent and the material is slightly more plastic. As is likely to be the case with alluvial soils, there is some variation in the texture, and small areas of a light fine sandy loam or very fine sandy loam are found. These, however, are not of sufficient size to separate from the surrounding areas of silt loam. In places the deep subsoil may contain layers of very fine sand, but such occurrences are comparatively rare. The type as a whole is easily tilled.

The Genesee silt loam is widely distributed throughout that section of the county east of Shawangunk Mountains. It does not occur in large bodies, but as narrow bands of first-bottom soil along many of the streams of the county. It is most extensively developed along the Wallkill River. The topography is flat to slightly ridgy and drainage is only fair.

Hickory, elm, soft maple, willow, and linden are the principal native trees.

As the Genesee silt loam is a first-bottom soil, subject to overflow, and is usually developed as narrow strips, it is generally utilized as pasture land, which is probably its best use. Where the areas are large enough to be cultivated corn and root crops are successfully grown. The soil is very productive and, when it is not overflowed during the growing season, corn produces 80 to 90 bushels and hay 1 to 2 tons per acre.

Commercial fertilizers are not used and as a rule are not needed, the high organic content and the frequent overflow keeping the soil productive. In many localities drainage is badly needed and protection from floods is generally necessary.

As this type is always held in connection with the surrounding upland soils, it is difficult to estimate its value separately. It is probably worth from $50 to $75 an acre.

HUDSON SERIES

The surface soils of the Hudson series are predominantly brown, ranging to yellowish. The subsoils are yellowish brown to yellowish in color, and are generally lighter in texture than the subsoils of the Vergennes series. The Hudson soils occur as glacial-lake terraces in the valley of the Hudson River. The material was deposited in glacial Lake Albany, and is composed mainly of wash from glaciated slate uplands. These soils are lighter in color than the Vergennes types, and are noncalcareous.

HUDSON GRAVELLY SANDY LOAM

The surface soil of the Hudson gravelly sandy loam consists of a brown to dark-brown gravelly sandy loam 6 or 8 inches deep. The

subsoil is a yellowish gravelly sand, changing in places at about 30 inches to a fine gravel. Both soil and subsoil are loose and open.

This type occurs in small areas, closely associated with other types of the Hudson series. The largest area is within the limits of the city of Newburgh. The topography is sloping to rolling, and surface drainage is good. The texture and structure are such that artificial underdrainage is not needed.

Owing to its loose, open structure and low content of organic matter the type is quite susceptible to drought. This thoroughness of drainage makes the soil warm up early in the spring, and for this reason it can be used in growing early truck crops.

HUDSON GRAVELLY LOAM

The Hudson gravelly loam consists of 8 to 10 inches of brown to dark-brown gravelly loam or light loam, underlain by yellowish-brown gravelly loam, gravelly sand, or gravel. The soil and subsoil are light and open, and the drainage, both surface and internal, is good to excessive. Where the surface features are favorable, the soil is easily tilled.

Only small areas of this soil are found in Orange County. The type is best developed in the vicinity of Newburgh, Cornwall-on-the-Hudson, Woodbury Falls, Central Valley, and Arden. The deposits are much deeper than those of any other terrace soil mapped in this county. Large quantities of shale and slate fragments are found, with fragments of quartzite, sandstone, and limestone. The immediate surface does not always show stratification, but within a few feet of the surface layers of assorted, waterworn material occur.

Little of this soil is under cultivation. Some truck crops are grown near Newburgh, while a few other areas are used in the production of the general farm crops. It is an early soil and gives good returns where used in trucking.

HUDSON FINE SANDY LOAM

The Hudson fine sandy loam consists of a dark-brown, friable sandy loam about 12 inches deep, underlain by a light-brown to yellowish-brown fine sand to light fine sandy loam. Below the 3-foot section the material grades into a sand. The subsoil generally has the same texture as the soil. The organic content is low, and the soil appears lighter than it actually is.

The Hudson fine sandy loam is encountered south of Newburgh. It has a small total area, and occurs as a high, nearly level terrace, which rises abruptly from the Hudson River to an elevation of about 100 feet. The drainage is good and crops do well, even in unusually wet seasons.

Most of the area of this soil is in cultivation. It is an excellent trucking soil, its open structure allowing free drainage and making it one of the earliest soils in the county. The produce from this soil is sold in the local markets.

HUDSON SILT LOAM

The surface soil of the Hudson silt loam consists of a friable brown silt loam, varying from 6 to 8 inches in depth. The subsoil is a light-brown to yellowish silt loam, extending usually without change to a depth of 36 inches or more. The line of demarcation between the soil and subsoil is usually quite distinct.

The only areas of Hudson silt loam in the county occur along the Hudson River in the vicinity of Newburgh. This type is closely associated with the other soils of the Hudson series and has the same general surface configuration. The topography ranges from sloping to rolling, and the surface drainage is usually good. The internal drainage, however, is generally inadequate, and artificial underdrainage is needed in many places.

The native vegetation includes elm, oak, hickory, and some pine and hemlock, with many smaller plants and shrubs.

Well-drained areas of this type give good yields of the general farm crops, such as corn, oats, rye, hay, and potatoes. Fruits are also grown successfully.

GRAY SOILS

WATER-LAID MATERIAL—SHALE AND SANDSTONE

Basher Series

The surface soils of the Basher series are gray. The subsoils are gray to pale yellow or yellowish gray. They occur in northeastern United States. These are first-bottom soils, derived from glacial drift composed mainly of sandstone and shale material from the glaciation of Shawangunk conglomerate and the Medina and Oneida sandstone. They comprise poorly drained material which in some other areas has been mapped as Genesee.

BASHER SILT LOAM

The surface soil of the Basher silt loam, which is about 12 inches in depth, consists of dark-gray or brownish-gray silt loam. The subsoil is a light-yellow and gray mottled silt loam to 30 inches, where the color changes to mottled gray and chocolate. The surface soil is friable and is easily maintained in a good tilth.

The Basher silt loam is encountered only in the Neversink River Valley and in the valley of one of its tributaries, the Basher Kill. The total area is small. The type is a first-bottom soil, formed by

deposition of sediment over the flood plains of streams. In position it is similar to the Genesee, Clyde, and Wallkill soils.

Agriculturally, the Basher silt loam has no value at present, except as pasture and hay land. It is not devoted to intertilled crops, largely because of the frequency of floods. It is flat, low lying, and greatly in need of drainage.

MISCELLANEOUS MATERIAL

MEADOW

In texture the surface material of the Meadow type varies widely, ranging from a silt loam to sand or even clay. Some areas are quite mucky, but owing to the high content of stones and bowlders in such areas, no separation of muck was made. The subsoil varies quite as widely as the surface soil in texture, but is generally heavy or clayey. It is more or less impervious. The color of both soil and subsoil is generally dark, though the subsoil is gray or brownish gray in places. In depth the soil and subsoil are quite variable, although the surface soil usually is comparatively shallow.

Meadow comprises low-lying, poorly drained areas. These occur along stream courses or in depressions which are too wet for cultivation unless properly drained. In most cases the soil is very stony, and in some instances the areas are too stony to make good pasture land. Meadow is distributed over the entire county, generally in long, narrow, irregular strips. Along streams it is often mapped where the bottom soils are variable and no distinct type can be recognized.

The material of this type consists of wash from the surrounding slopes and uplands, with an accumulation of decaying organic matter. The areas usually support a good growth of shrubs, trees, and water-loving plants, grasses, and rushes. The principal trees are elm, soft maple, and occasionally water beech.

The agricultural value of Meadow is low. Owing to its wet condition and high content of stone, cultivation is practically impossible. Where not too stony and where properly drained, the type furnishes good pasture, and in many cases the swamp grasses are cut for hay. Some of the type can be improved and made tillable, but in most cases the expense of draining and removing the stones would be so great as to render reclamation impracticable.

MUCK

Muck is the most valuable agricultural land in the county. It varies somewhat in texture and color. In general, it consists of black or brown decayed organic matter. The surface material, extending to a depth of about 9 inches, is darker in color and finer in texture than the subsoil. In a few areas both the soil and the subsoil are gray. In places the deep subsoil is a brown, coarse, peaty material. The depth of Muck varies from a few inches to many feet. Near

Pine Island it is at least 18 feet in depth, and in other areas its depth ranges from 12½ feet to 18 feet. These deep deposits occur usually in the largest areas.

Muck is encountered in nearly all sections of the county, occurring in areas ranging from patches too small to be shown on the map to areas several square miles in extent. The largest and most valuable are located in the Wallkill River Valley between Denton and Florida, and extend south to the county line along the river. Other large areas occur near Chester, Mount Hope, and Smith Corners, and in the vicinity of Orange Lake. All of these occupy low-lying positions, and are naturally swampy. The poor drainage has been responsible for the formation of this soil type, which is due to the luxuriant growth of water-loving plants and their decay. The Muck contains more or less mineral matter. This is most abundant in the surface few inches and near the streams. It has been washed from the uplands and deposited in the depressions or along streams. Near the streams the mineral matter is distributed throughout the soil section. Marl sometimes occurs under very small areas.

The surface of the Muck areas is nearly level. This feature, together with their low-lying position, makes the natural drainage inadequate, although in nearly every case artificial drainage is feasible.

Those areas of Muck upon which elms and soft maples thrive are valued much more highly than those upon which cedars or tamaracks grow. In general, the soil will grow almost any of the farm crops except the small grains. Corn is probably the principal grain crop. Hay also is grown extensively. These two crops give excellent yields, as do potatoes. Hay produces as high as 4 tons per acre, corn as high as 75 to 100 bushels, and potatoes from 100 to 300 bushels per acre.

In Orange County the greater part of the area of Muck under cultivation is utilized for the production of truck crops, such as onions, celery, sweet corn, carrots, parsnips, spinach, beans, and lettuce. Of these, onions, lettuce, and celery are the most important.

Celery growing on the Muck is very remunerative. From $300 to $500 per acre is received from this crop. Fertilizer of a 2–8–10 composition is used for this crop at the rate of from 1,000 to 2,000 pounds per acre. Large quantities are applied in growing the other truck crops.

The agricultural conditions on cultivated areas of Muck land are good. The most intensive type of farming in the county is practiced on this soil. The land ranges in value from $50 per acre for uncleared, undrained land to $500 or more an acre for land which has been reclaimed and is under cultivation. The great markets of the East—New York, Boston, and Philadelphia—are readily accessible, so that the Muck type is very valuable for the special truck crops to which it is so well adapted.

ROUGH STONY LAND

The Rough stony land of Orange County includes those areas which are too steep and stony or have too thin a soil mantle for cultivation.

This type occurs in practically all parts of the county, mainly along the tops and slopes of the ridges, although it is also encountered in the valleys and at the foot of ridges, where the rocks have been moved from the higher elevations. It is most extensively developed in the mountains of the southeastern part of the county, south and west of Warwick, along the Shawangunk Mountains, and on the Catskill Plateau in the western part of the county. The gneissic and granitic region of the southeastern section holds the largest areas and those of most rugged topography. The crystalline limestone in the vicinity of Warwick also gives rise to several areas of Rough stony land.

The forest growth includes principally oak, pine, hemlock, and chestnut, with some small cedar. Hemlocks are generally found along the streams and in the ravines. The undergrowth of brush consists mainly of rhododendron. Agriculturally the Rough stony land is of little value. Where it occurs in connection with arable types of soil it produces some revenue as pasture and wood lot.

ROCK OUTCROP

Rock outcrop in Orange County consists of those areas where bare rock and ledges occupy so much of the surface as to render them of no agricultural value.

These areas occur mainly in the Highlands and on Schunemunk and Shawangunk Mountains. Some smaller areas occur on the Catskill Plateau and in various other sections of broken topography. Areas mapped as Rock outcrop are unfit for any use except forestry, and most of its area can not be used even for this purpose.

MADELAND

The Madeland classification includes locations where the surface has been changed by the construction of extensive railroad yards, as at Maybrook, Port Jervis, and Newburgh, or by the building of docks along the Hudson River, as at Newburgh and Cornwall Landing, or by mining, as in case of the excavations made to obtain clay for brick manufacture at New Windsor, Roseton, and Jovas. At West Point many changes in the natural conditions have been made by blasting out rocks to be used in the construction of buildings and hauling in earth to replace the material removed. All such areas are included with this classification, but their total area is small, and the type has no present or prospective agricultural value.

SUMMARY

Orange County is situated in the southeastern part of New York west of the Hudson River. It has an area of 834 square miles, or 533,760 acres. The topography ranges from nearly flat or rolling to mountainous. The elevations range from tide level to about 1,680 feet above sea level. The entire county has been glaciated.

The drainage is through two systems, the Hudson and the Delaware River. The largest tributary streams in the county are the Wallkill and Neversink Rivers.

The population in 1910 was 116,001. Newburgh is the largest city, with a population of about 28,000, and Middletown the second largest city, with 15,000. Goshen, the county seat, is centrally located on the Erie Railroad, and has a population of about 3,000. Many small towns are scattered throughout the county.

Railroads reach all sections of the county except the most remote and mountainous regions. These, with the steamboat lines on the Hudson River, furnish excellent shipping facilities.

Most of the farm products find ready markets either in the cities and towns of the county or in New York City, which is only a few hours distant.

The mean annual temperature is about 49° F. There is a mean annual rainfall of about 46 inches. The average growing season comprises 161 days.

Dairy farming and fruit growing are the principal industries. Dairying has increased steadily since the development of the railroads began. Butter making was formerly the most important branch of this industry. The shipping of milk began in 1842. This is now the principal branch of dairying in the county.

Fruit growing began to receive special attention about 1880. It is now an important industry. Apples, pears, peaches, and plums, and all kinds of small fruits are grown.

Trucking is most extensively practiced on the Muck soils, but is carried on to some extent on the light upland soils. Onions, celery, and lettuce are the most important crops on Muck.

The general farm crops now grown are mainly those needed in the dairy industry. Hay is the most important crop; next in order are corn, oats, rye, and potatoes. Much of the grain used for feeding is shipped into the county.

Crop rotation is practiced to some extent, but not systematically. The soils are adapted to a wide range of crops, and the need of rotations to include more grain and leguminous crops is obvious.

Forty types of soil are mapped in Orange County. They conform closely to the characteristics of the rocks from which they are derived by glaciation. Those soils associated with the crystalline rocks

are included in the Gloucester series; those derived from limestone are classed with the Dover series; and the soils from glaciated shales and sandstones give rise to the Culvers, Dutchess, and Otisville series. The terrace soils of the valleys are classed in the Hudson and Hoosic series, the latter being derived from assorted and reworked glaciated material from the Hudson River formation. Small areas of Fox soil and Merrimac soil are also mapped. The former is water-laid material, derived largely from limestones, and the latter from crystalline rocks.

The terrace soils west of the Shawangunk Mountains are derived from sandstone material and are included in the Chenango series. The stream bottoms have given rise to a number of soils—the Clyde, Wallkill, Genesee, Basher, Muck, and Meadow.

Rough stony land, Rock outcrop, and Madeland are classifications rather than types. They are nonagricultural.

The Dutchess silt loam and stony loam are the most extensive soils in the county, and are the ones used most for general farming and dairying. The stony loam and shale loam of this series are the most important fruit soils.

Muck is the most valuable land in the county. It is held at $50 to $500 an acre. The most intensive system of farming in the county is practiced on this type.

Many of the soils of the county require draining in order that best results with crops may be had. The Muck and other bottom soils are most in need of drainage, and a large part of the upland soils would be decidedly benefited by underdrainage, even where the surface drainage is good.

There are 3,935 farms in Orange County. The average size of the farms, according to the 1910 census, is 97.6 acres. The value of all farm property is given as $35,516,309.

The values of farm land and farm products are increasing yearly. This is reflected in the improved condition of the farms and buildings. Improved roads are being built, which make all parts of the county easily accessible to market and shipping points.

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AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Soil Technology

EFFECTS OF VARIATIONS IN MOISTURE CONTENT ON CERTAIN PROPERTIES OF A SOIL AND ON THE GROWTH OF WHEAT

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CONTENTS

EFFECTS OF VARIATIONS IN MOISTURE CONTENT ON CERTAIN PROPERTIES OF A SOIL AND ON THE GROWTH OF WHEAT

Franklin S. Harris

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INTRODUCTION

Moisture is probably the most important single factor affecting plant growth, and it is certainly a powerful agent in influencing the chemical, physical, and biological changes going on in the soil. The fact that the amount of moisture in the field is so variable and so difficult to control, has always made this factor a troublesome one in experiments with soils and crops. Often, when it has been desired to determine the effects of a certain treatment, these effects have been so completely overshadowed by unavoidable changes in the amount of moisture that the results have been valueless.

A practical examination usually shows that in many agricultural sections the availability of moisture is the chief problem confronting the tillers of the soil. In some regions the total annual rainfall is barely sufficient for plant growth. There are other regions where the rainfall would be sufficient to meet the needs of crops if it were properly distributed or if the crop growth could be adjusted to use the precipitation most economically. There are also hundreds of millions of acres of good agricultural soil in regions where the rainfall is just below the amount necessary to make crop-raising profitable with present methods. Most of this land might become productive if the efficiency of the scant supply of moisture were raised to the optimum. Even in regions where there is sufficient precipitation to meet all crop requirements the question of moisture is important, since an excess affects certain properties of the soil that may determine its fertility. Any facts, therefore, that will throw light on the intimate relations between moisture and crops, as well as between moisture and changes going on in the soil, are of much practical importance in helping to solve the great problem of increasing the area of productive soil and making more efficient that which is at present cultivated.

In view of this great practical problem, as well as the theoretical considerations already mentioned, it was thought desirable to conduct a series of experiments under strictly controlled conditions, wherein the soil moisture would be the varying factor, to determine as many of the effects of this factor as possible, both on the soil and on the crop. The fact that these effects are modified by fertilizers and by the period at which moisture is applied to plants, made it desirable to test fertilizers

in connection with the moisture and to change the soil humidity at various periods in the growth of the crops.

The plan was carried out, and the following observations were made on wheat plants under conditions to be later described in detail: (1) growth and morphology of the plants, including length of the periods of growth, tillering, form and structure of the different parts, and general observations during growth; (2) yield and relative quantities of the different parts of the plants; (3) transpiration of the plants, including the total water used, the relation between this and the dry matter produced, the quantity used during various stages of growth, and the relation of transpiration to temperature, sunshine, and humidity of the air; (4) composition of the plants. The effects of some of the same conditions on the following properties of the cropped and the uncropped soils were also studied: volume of the soil, flocculation, nitrates, nitrites, ammonia, total water-soluble salts, number of bacteria, and amount of easily soluble phosphoric acid. Before the experiments themselves are considered, the work of various investigators of the subject will be briefly reviewed.

REVIEW OF LITERATURE

The great importance of water in plant growth and in modifying soil conditions was early recognized by investigators; hence the literature that has accumulated, especially regarding the relationship between crops and moisture, is exceedingly voluminous. It will be necessary, therefore, to limit the number of citations and to omit many important ones.

Much of the literature studied by the author, concerning the effects of moisture on certain of the properties of the soil, is so fragmentary that it will not be presented in great detail. More attention will be given to the literature covering moisture and crop relations. Indeed, it is with this phase of the general subject that most of the author's experiments deal. The work of the various investigators will be brought together under the headings used for the experimental work in the main body of the bulletin.

Relation of moisture to certain properties of the soil

Schlosing pointed out, more than forty years ago, that the quantity of nitrates found in a soil increases with the humidity, when there is not sufficient humidity to wet the soil to the extent that a free passage of air is interfered with; and Warington found later that where there is a great excess of water in the soil, denitrification takes place.

Gain (1895 a)[1], in connection with other important work, showed that

[1] Dates in parenthesis refer to bibliography, pages 860 to 868.

soil moisture has a great effect on the action of bacteria. He found that a medium moisture content (about fifty per cent of saturation) is the most favorable for tubercle formation.

King has done considerable work on soluble salts and nitrates, and the relation between them under various climatic and cropping conditions. He found that the ratio of total soluble salts to nitrates varies between 2.14:1 and 9.97:1 under different conditions. The total soluble salts, and especially the nitrates, are higher in fallow than in cropped soils. The crops also seem to take up the nitrates faster than the other soluble salts. These results are summarized in "A Text-book of the Physics of Agriculture," pages 92–107.

Stewart and Greaves (1909) found that on an uncropped soil, to a depth of ten feet, there is more nitric nitrogen in a soil receiving a medium irrigation than in one receiving no irrigation. Immediately after irrigation, however, there is less nitric nitrogen in the surface foot of the irrigated soil than in the surface foot of the non-irrigated soil.

Jensen (1910), in agreement with the work of many other experimenters, found more nitrates in summer-fallowed soil than in soil cropped with wheat or corn.

Buckman (1911) has shown that under dry-farm conditions the formation of nitrates is greater where there is a good supply of soil moisture than where the soil is dry.

Free (1910) has thrown considerable light on the question of flocculation and the way in which it is affected by different soil treatments.

Davis (1911) showed the effect of a number of the soluble salts in modifying the flocculation and other physical properties of the soil.

Ellett and Hill (1913) found that the application of phosphate fertilizer to soils of limestone derivation can be detected by fifth normal nitric acid the year after its application. The addition of fertilizers does not seem to influence the water-soluble phosphoric acid in such soils.

Lyon and Bizzell (1913 b) have clearly shown that the formation of nitrates is influenced by the crop growing on the soil.

Relation of moisture and fertilizers to the growth and morphology of plants

Length of period of growth.— Schroeder (1896) found that the length of the period of growth of barley is prolonged in proportion to the quantity of water available to the plants, and is also affected by the amount of salts contained in the soil. Abbe (1905) and Mayer (1898) both reported experiments wherein the crops matured earlier in dry than in wet soils.

Tinsley and Vernon (1904) found that on an adobe soil in New Mexico excessive irrigation retarded the ripening of grain for a few days.

Prianishnikov (1900), on the other hand, found that the period of vegetation of wheat was somewhat shorter when the moisture was greater.

Von Seelhorst and Krzymowski (1909) found that the way in which moisture affects the date of ripening depends somewhat on the variety of wheat, but is always later with seventy per cent saturation than with more or less water. It must be borne in mind, in considering the various experiments with moisture, that what one investigator calls high moisture another might call medium, or even low. This fact will explain some of the apparent discrepancies between the work of various investigators.

Tillering and miscellaneous observations.— Schroeder (1896) found that the development of adventitious stalks, or tillers, in barley is more pronounced with greater concentration of salts for the same humidity.

Lyon (1907) showed that tillering is favored by a rich soil, and also by cool nights and hot days.

Von Seelhorst (1900), testing the effects of different amounts of moisture on the form of oats and spring wheat, found the following results: With oats the high percentage of water during the early periods of growth increased the number of internodes, and during the period of heading it increased the length and strength of the culm. A high soil-moisture content when the plants were heading considerably lengthened the two upper internodes and the rachis. The number of zigzags in the rachis, as well as the number of spikelets, was increased by a high percentage of water during early growth; while the number of blossoms developed in the spikelets was relatively much greater when the water content of the soil was high at the time of heading than when it was low. The results with wheat were in many respects the same as with oats, but the effect of the water content during the early period of growth was not so marked. The length of the head of wheat depended on the high water content during the early vegetative period. Increasing the soil moisture at the time when the wheat began to head did not increase the number of spikelets, but it was very effective in increasing the number of developed blossoms.

Von Seelhorst and Georgs (1900) found that high soil moisture with high nitrogen fertilizers favors tillering in barley. It also causes the number of internodes to be increased, as well as the length of each internode. The length of heads is likewise affected, being increased by high nitrogen fertilizers and high moisture together, but shortened when high moisture is maintained without the fertilizer.

Preul (1908) found that the length of the wheat culm depends on the moisture content of the soil at the time of sprouting, and that the length of the head depends on the soil moisture during early stages of growth.

Ohlmer (1908) and Meyer (1909) showed that the amount of soil moisture and fertilizers has a great influence on the shape, as well as on the size, of wheat heads.

Eberhardt (1903), as a result of studies with moisture on a large number of plants, concluded that excessive drought results in the dwarfing of the stems, associated with an increased rigidity and diminished length of stems but with an increase in the number of internodes. There was also a reduction in the size of the leaves, an increase in their thickness and in the intensity of color, an increase in hairiness, and an earlier leaf fall. Eberhardt's work included also microscopic studies of structure.

Kolkunov (1905) also has made many histological examinations of plants inured to drought.

Gain (1895 b), in his very extensive work on the physiological rôle of water in plants, says that humid conditions augment the number of seeds and fruits produced, while drought decreases inflorescence and number of seeds. He lays great stress on the periods during which plants should receive various degrees of soil humidity.

Hellriegel, and afterwards Wagner (1908), showed that during early stages of development the root growth of plants is proportionately greater that during later stages.

Preul (1908), von Seelhorst and Georgs (1900), Schroeder (1896), Bünger (1908), and Kiesselbach (1910), all brought out the fact that root growth is proportionately greater in a soil low in humidity, or in one low in fertility, than under the opposite conditions.

Polle (1910), studying the effect of fertilizers, moisture, and compacting on the ratio of roots to tops of barley and wheat, found that one gram of roots produces a larger quantity of aboveground parts in both clay and sand when fertilized than when not fertilized, a larger quantity in a moist soil than in a dry soil, and a larger quantity in a compact soil than in a loose soil.

Pfeiffer, Blanck, and Friske (1913), after experimenting for two years with several kinds of soil receiving different quantities of water, concluded that the ratio of grain to total yield decreases as the water supply increases. The nitrogen content of the crop decreases, while the potash, and especially the phosphorus, increases, with increase of water supply.

Von Seelhorst (1911), as a result of the work of fourteen years, found that the soil moisture is capable of influencing the ripening period to such an extent that varietal characters are lost.

Relation of moisture and fertilizers to crop yields

Von Seelhorst (1900) pointed out the importance of a high soil humidity for oats at the time of heading, in increasing the yield of straw and grain. Later von Seelhorst and Krzymowski (1905) showed the effect of high and of low soil moisture, during the various stages in the growth of plants, on the yield of grain and of straw.

Tinsley and Vernon (1904) concluded that wheat will do well, up to the time when the heads fill, in a soil that would be comparatively dry for corn; and that if the soil is kept moist at the time of filling, the yield will be about as good as if the high moisture content had been maintained throughout the season.

Von Seelhorst and Georgs (1900) found an increase in the weight of heads when high moisture accompanied a nitrogen fertilizer; but the ratio of grain to the entire plant decreased with high soil moisture when a nitrogen fertilizer was not applied to soil deficient in nitrogen.

Mayer (1898) concluded, after working for a number of years with rye, wheat, oats, and barley, that, as a rule, the less the moisture, the greater is the relative growth of grain. Bünger also came to the same conclusion.

Widtsoe (1902) found that the percentage weight of heads is greater for heavy irrigations than for light; also that late irrigations are good, for the yield of wheat in particular, and that they are helpful in transferring nutritive materials from the stalks to the heads.

Pulman (1904), working with buckwheat, decided that it is impossible to get a good yield without a high soil humidity at the time when the seed is forming.

Waters and Hess (1896) found with wheat that the largest yield of straw was from plats receiving a complete commercial fertilizer, and especially from those receiving high nitrogen.

Fleischer (1897) observed an almost uniform widening of the ratio between grain and straw with increased nitrogen content of the soil.

Prianishnikov (1900) found, contrary to the results of many other investigators, that increased soil humidity did not decrease the relative quantity of grain in wheat plants.

Preul (1908) brought out the facts that abundant soil moisture succeeding a dry period produces a high grain yield in wheat, and that dry soil at the time of heading is especially harmful. A lack of water during later stages of growth lowered the weight of one thousand kernels, especially on rich soil.

Gain (1895b) showed that, while dry soils decrease the number of seeds produced, the seeds that are grown are larger and heavier than those grown on wet soils.

Le Clerc (1907) observed that the weight of one thousand kernels is usually greater in wheat from irrigated and humid regions, while arid regions produce a higher percentage of flinty kernels.

Von Seelhorst and Bünger (1907) found that the number of kernels of wheat per head rise with the following conditions: (1) an increase in soil moisture; (2) high nitrogen fertilizer; (3) usually with a thin stand; and (4) large heads. They found also that the weight of one thousand

kernels is influenced as follows: (1) nitrogen fertilizer lessens the weight of kernels on low soil moisture, but raises it with high moisture; (2) high moisture lowers the weight on nitrogen-poor soil, but increases it on nitrogen-rich soil; (3) a thick stand usually lessens the weight of kernels.

Lyon (1905) showed that plants bearing the largest number of kernels have kernels of more than medium, but not the greatest, weight; also that the weight of the average kernel does not increase with the size of the head, nor does it decrease except on the very largest heads.

Widtsoe and his associates at the Utah Agricultural Experiment Station[2] have contributed greatly to our knowledge of the effect of irrigation water on soils and on crops. The advantage of these experiments is that they were conducted in the field under regular cropping conditions. Medium applications of water were found to be the best in economizing moisture.

Transpiration

Sachs, Burgerstein, and others have long since shown that certain substances in the soil and in culture solutions may greatly retard or accelerate the rate of transpiration in plants.

Reed (1910) did considerable work on the specific effect of certain acids, bases, and salts on transpiration in wheat seedlings grown for two or three weeks.

Gain (1895 a) brought out many points in regard to transpiration. He showed that it is increased with high soil moisture until the " maximum of turgescence " is passed, after which it decreases.

Abbe (1905) gave the factors influencing transpiration as follows: (1) quantity of water available to the plants; (2) temperature and dryness of the air; (3) velocity of the wind; (4) intensity of the sunlight; (5) stage of development of the plant; (6) quantity of foliage; and (7) nature of the leaf. He records that it was found by S. H. Woodward, as early as 1691, that the amount of water necessary to increase one gram in the weight of plants varies with the amount of nourishment in the water — the water of the Thames River, with its considerable supply of plant-food, being used much more economically than pure spring water. Abbe showed that the amount of water used in producing a given amount of dry matter varies with the season.

Lawes (1850) concluded, after using a number of fertilizers with wheat, barley, beans, peas, and clover, that there is a greater economy in the water transpired by wheat, peas, and clover when mineral fertilizers are present, but that with beans, under certain conditions, the fertilizers produce the opposite effect.

[2] See bibliography, under Widtsoe and others, pages 867 and 868.

Heinrich (1904) showed that the humidity of the atmosphere influences the relationship between the water transpired by oats and the dry matter produced. In an atmosphere kept constantly humid, only 102 grams of water were transpired for each gram of dry matter, while in the dry atmosphere 618 grams were required. Heinrich showed also that plants growing in a concentrated nutrient solution transpire water more economically than when growing in a dilute solution.

Maercker (1896) concluded that dry matter is produced with less water when potash salts are used as fertilizer.

Schroeder (1896) found that the transpiration of barley is in proportion to soil humidity and the concentration of the nutritive material present. The quantity of water evaporated per unit of dry matter increases with the concentration of the medium until the latter reaches a certain concentration, beyond which it falls.

King, whose work is described in the annual reports of the Wisconsin Agricultural Experiment Station from 1891 to 1893, has perhaps studied, more than any one else in this country, the relation between transpiration and dry weight of crops produced. He worked out the average quantity of water used by a number of crops under Wisconsin conditions (1907: 139). He showed also that rapidly growing, vigorous plants produce more dry matter with the same quantity of water than do weaker plants, and that water is used more economically on summer-fallowed than on continuously cropped land (1893a and 1894a).

Pagnoul (1898) found that in poor soil about twice as much water is required in order to produce a unit of dry substance in fescue grass as in rich soil.

Von Seelhorst (1899) found, with oats, that the water required in order to produce a unit of dry weight decreases as the luxuriance of growth increases; also that the balance between the fertilizer constituents, as well as the nature of the soil, influences the relation between water used and dry substance produced. He later (1906) found that water is used more economically on a loam than on a sandy soil.

Warington (1900), comparing the results of Lawes and Gilbert, Hellriegel, King, and Wollny, concluded that the relation between water used and crop produced is influenced, first, by the quantity of water supplied, and second, by the richness or poverty in plant-food.

Yanovchik (1900) observed that wheat transpires water more economically with a medium soil humidity than with soil very wet or very dry.

Fortier's (1903) results from applying irrigation water to oats in tanks show that more water is used in producing a pound of dry weight of crop with both the very large and the very small irrigations than with the medium irrigations.

Morgan (1912), working with plants in wire baskets, also found a medium degree of soil moisture most economical in producing dry matter.

Widtsoe (1902) showed that crops require more water in order to produce a pound of dry matter in arid than in humid regions. He later (1909) worked out the effect of a number of factors in affecting the relation between transpiration and dry substance produced. The fallowing and cultivation of the soil, the soil fertility and humidity, the season, the crop, and the method of applying water, were all shown to be important in affecting this relation. Fertile soils and summer-fallowed soils were especially economical in their use of water.

Livingston (1905) concluded that transpiration and growth are proportional under various conditions; but his results, as well as those of other experimenters, do not justify this conclusion.

Gardner (1908) found that fertilizers which are most efficient in increasing the green weight of seedlings also cause water to be transpired most economically.

Preul (1908) found, with wheat seedlings in zinc tanks, that less water is required for a unit of dry substance in fertile soil than in poor soil.

Kiesselbach (1910) concluded that soil humidity, and concentration of nutrient solution added to corn, have no great effect on the relation between dry matter and water transpired. His tables, however, do indicate differences for both these factors.

Heinrich (1904) showed that the absolute amount of water transpired increases from week to week until about the time of blooming, and then decreases.

Livingston (1906), studying soil moisture and evaporation in relation to desert plants, concluded that the temperature of the air is the most important factor in controlling transpiration.

Leather (1910–1911), working in India, investigated a number of the factors influencing the water transpired by certain of the crops. Soil moisture and fertilizers were given particular attention.

Bouyoucos (1912) found that there is a close relation between the concentration of the nutrient solution and the transpiration ratio. Increasing the density of the solution caused water to be used more economically. The various ions in the solution were found to exert an influence on the economy of transpiration.

Lyon and Bizzell (1913 a) have shown that a greater quantity of dry matter per unit of transpiration is produced in fertilized than in unfertilized soil, and they suggest the use of this transpiration ratio as a means of determining the relative density of the soil solutions.

Montgomery and Kiesselbach (1912) found that manure decreases the water requirements of corn; but they doubt whether, under field con-

ditions, adding manure to soils of good fertility would decrease the water requirements.

Briggs and Shantz (1913, a and b) have prepared a good summary of literature on the water requirements of plants, and they report a number of experiments made under their direction during 1910 and 1911. They show the effect of crop and variety, as well as of climate, on the quantity of water required in order to produce a unit of dry matter. At Akron, Colorado, alfalfa used the greatest quantity of water, while millet used the least. Wheat required about twice as much as millet and about one half as much as alfalfa.

Khankhoje (1914), working at the Washington Agricultural Experiment Station, found the following factors to influence the water requirements of crops: (1) kind of crop; (2) strength of soil solution; (3) age of plants; (4) amount of moisture in the soil.

Relation of moisture and fertilizers to the composition of plants

Nitrogen.— Mayer (1898), working for a number of years with rye, wheat, barley, and oats, found that, as a rule, the less the moisture, the lower is the percentage of fiber and the greater is the percentage of protein and pure albuminoids. The water requirements of these plants were placed in the following order, from greatest to least: oats, wheat, rye, barley.

Wilms and von Seelhorst (1898) pointed out that increasing the soil moisture reduces the nitrogen content of both grain and straw of oats, but that variations in nitrogen content due to water supply are more marked in straw than in grain. The nitrogen content of the crop is affected also by fertilizers. Similar results were obtained by Prianishnikov.

Widtsoe (1902), working under irrigation conditions with corn, wheat, potatoes, and sugar beets, found that with the same climatic conditions a high amount of irrigation water diminishes the percentage of protein but increases the percentage of nitrogen-free extract and fat. In wheat the protein was eleven per cent higher when grown with low irrigation than when grown with high irrigation.

Traphagen (1903) showed that when low-protein wheat from an irrigated field is planted under dry conditions the percentage of protein is greatly increased.

Whitson and Stoddart (1904) observed a higher percentage of protein in crops grown on soil with a good supply of nitrates than in crops grown on soil with a low supply of nitrates.

Von Seelhorst and Fresenius (1905) showed that with oats a high soil moisture causes a lower rate of decrease in the proteid nitrogen than

in total nitrogen, also a less decrease in the digestible proteid nitrogen than in the total proteid nitrogen.

Lyon (1905) pointed out that the increase in nitrogen due to a deficiency of moisture is often caused by the shortening of the growing period, and that the weight of proteid nitrogen in the average kernel is less in the early-maturing plants. He showed also (1910) that hardness of kernel and high percentage of nitrogen are always associated.

Le Clerc (1907), comparing a large number of results with wheat grown under humid and under arid conditions, found that high nitrogen is associated with arid conditions.

Preul (1908) showed that the nitrogen content of grain and straw grown on rich soil is higher than in that grown on poor soil; also that constant low moisture, on both rich and poor soil, increases the percentage of nitrogen, but a lack of moisture at late stages of growth lowers the nitrogen content of grain. In the case of straw, the nitrogen content is lowered on the rich soil but increased on the poor soil.

Shutt (1909) pointed out that in Manitoba newly broken land, as well as moist irrigated soil, produced starchy grain lower in nitrogen than grain grown on old soil or soil with a low moisture content.

Frei (1910) found the nitrogen content of oats to be influenced by moisture, distance of planting, quality of soil, and a number of other factors.

Hunt (1904) states that "a cool, prolonged, but not too wet spring, followed by moderately dry sunny weather during ripening, is most favorable to the largest yield of the best quality" of wheat. He also believes any shortening of the period of growth to be the chief factor in raising the percentage of nitrogen in wheat.

Schindler (1893), as early as 1893, stated that the protein content of the wheat kernel depends in the first place on the length of the growing period, and secondly on the richness of the soil.

Thatcher (1912 and 1913) has done a large amount of work on the factors affecting the composition of wheat. He held that the relative protein content of grain is determined chiefly, if not wholly, by the rapidity of ripening of the kernel after it is once formed. He found also that the moisture supply is a very important factor in determining the composition of wheat grown in any given locality or season.

Ash constituents of plants.— Wilms and von Seelhorst (1898) discovered that the ash content of grain varies with the quantity of water in the soil, increasing rapidly up to the point of medium water supply, but more slowly beyond that point. The fertilizer producing the lowest yield of grain gave grain with the highest percentage of ash. The effect of moisture and fertilizers on the potassium and phosphorus content

of the ash under various conditions was also worked out in some detail.

Von Seelhorst, Georgs, and Fahrenholtz (1900) found that the percentage of ash in rye grass and in clover usually increases as the soil moisture increases, up to the limits used by them.

Gamble (1906) found plants grown in surface soil in pots to have a somewhat higher ash content than plants grown in the field. This was attributed in part to the moisture supply.

Hall (1905) has given some very interesting data regarding the ash of grain and straw as affected by manures and by the season at Rothamsted.

Le Clerc (1907) did not find any great difference in the percentage of ash and of phosphoric acid in grain grown under humid and under arid conditions.

Fest (1908) showed the effect of various fertilizers added to the soil on the composition of the ash of dwarf beans, and brought out many interesting relations. For example, a lack of nitrogen caused a decrease in nitrogen and potassium, but an increase in calcium.

Von Daszewski and Tollens (1900) found that soil moisture has a great influence on the ash of the potato. With high soil moisture the potato took up a larger amount absolutely, and a smaller amount relatively, of potassium and phosphoric acid, than with lower soil moisture. Relatively more calcium and chlorine, however, were taken up with the higher moisture.

Composition of plants at different stages of growth.— It was repeatedly observed, many years ago, that plants take up their mineral matter and nitrogen much faster while young than when they become older.

Hébert (1892) found that the percentage of nitrogen and that of ash are very high in oats and wheat at first, and gradually decrease to maturity.

Davidson (1895), working with tobacco, discovered that the percentage of total ash and that of most of the ash constituents are much greater during early periods than later. The percentage of calcium, however, is highest at the time of cutting.

Schulze (1904) concluded, from his experiments with rye and wheat, that practically all the assimilation of nitrogen, phosphoric acid, potash, and sulfur is complete at the time of heading. Calcium and magnesium are used to a somewhat greater degree during later stages.

Wilfarth, Römer, and Wimmer (1906), after years of work with a number of crops, advanced the theory that there is an actual return of mineral substances and nitrogen from the plant to the soil during the late stages of growth; this return being more marked with certain constituents and with certain crops than with others. Similar results have been obtained by Wagner (1908), Fest (1908), Seidler and Stutzer (1908), Déléano (1907), and a number of others. Le Clerc and Breazeale (1909), however, believe

this return to be due mainly to the washing-off of the ash constituents by rain water, rather than that it is a real return through the roots.

CONDITIONS OF THE EXPERIMENTS, AND METHODS USED

The experiments reported in the following pages were conducted in the greenhouse of the Department of Soil Technology at Cornell University during the winters of 1908–1909 and 1909–1910, and the analyses were made later in the laboratory of the same department.

The pots

Wheat plants were raised in three-gallon glazed earthenware pots containing a special device for measuring transpiration. This transpiration-measuring device, or potometer, which is essentially the one devised by Professor Montgomery at the Nebraska Agricultural Experiment Station, was arranged as follows: An ordinary earthen flowerpot three inches in diameter, containing a hole in the bottom, was inverted in the culture pot mentioned above. A thistle tube fifteen inches long had an inch or so of its lower end turned up to form a U. This was placed under the edge of the small inverted pot so that the lower end of the thistle tube was inside this pot, while the bowl end projected out above the large pot and served as a receiver for the water, which was conducted into the inverted pot below. From here the water could run out into the surrounding soil. There was also a glass tube to conduct the air out of the inverted pot when water was added. A small quantity of fine gravel was placed in the bottom of the main pot around the inverted pot, to improve aëration and facilitate the movement of water into the soil.

Soil having been put into the culture pot, the wheat was planted in two rows, then one half kilogram of crushed quartz was placed over the surface to serve as a mulch. When the plants were three or four inches high the pots were sealed with paraffined paper, in which were holes to allow the plants and the glass tubes to pass through. Thus there could be no escape of water except that transpired through the plants. The pots were weighed three times a week, and the loss that had occurred was made up with distilled water, which was added through the thistle tube as a subirrigation.

The soil

The soil used was taken from Caldwell Field, Plat 729, and had received no fertilizer for many years. It is described by the United States Bureau of Soils as the silty phase of Dunkirk clay loam.

A chemical analysis of the soil made from the extract of HCl sp. gr. 1.115 gave the following:

TABLE 1. CHEMICAL ANALYSIS OF SOIL

Constituents	Percentage
CaO	0.54
MgO	0.56
K_2O	0.183
Fe_2O_3	2.66
Al_2O_3	3.64
P_2O_5	0.15
Nitrogen	0.12
Moisture	1.54

Nine kilograms of moist soil were placed in each pot. This was equivalent to 7.65 kilograms of dry soil in 1908–1909 and to 7.70 kilograms in 1909–1910. Thus practically the same quantity of soil was used for each pot during the two years.

Fertilizers

During both years some of the pots were unfertilized and some were fertilized, two combinations being used. One set received the following:

Nitrate of soda, 0.771 gram per pot, or 300 pounds per acre
Muriate of potash, 0.257 gram per pot, or 100 pounds per acre
Acid phosphate, 0.771 gram per pot, or 300 pounds per acre

This combination was called "complete fertilizer," and will be so distinguished throughout the report of the experiments.

The other combination used will be distinguished as "high nitrogen fertilizer," and was as follows:

Nitrate of soda, 2.57 grams per pot, or 1000 pounds per acre
Muriate of potash, 0.257 gram per pot, or 100 pounds per acre
Acid phosphate, 0.771 gram per pot, or 300 pounds per acre

These fertilizers were added to the surface of the soil as dry salts, and were stirred into the upper two or three inches before the seeds were planted.

Stages in the plant growth

The life of the plant was divided into three stages, as follows: first, from planting until the plants had five well-developed leaves; second, from the five-leaf stage until the swelling of the culms showed the development of the head (this will be designated by its popular name, "boot stage"); third, from the boot stage to maturity. Some pots were kept

at the same humidity throughout the three periods, while others were changed during each period. All received the same quantity of water at first, in order to insure even germination; but when the plants were up, all pots received their proper quantity of moisture. Thirty seeds were planted in each pot, but when the plants were a few inches high all were removed except twelve plants of a uniform size. Duplicates were kept of all the cropped pots.

Arrangement and treatment of pots during 1908–1909

The following is the treatment received by the respective pots during 1908–1909. All moisture is stated on the basis of percentage of dry soil. The water-holding capacity of the soil was about 45 per cent of its dry weight when the pots were filled, consequently 15 per cent and 30 per cent of water as given would be 33 per cent and 67 per cent, respectively, of its water-holding capacity.

The uncropped pots, which were allowed to stand by the side of the cropped ones in order to determine the changes going on in the soil, were arranged as follows.

TABLE 2. TREATMENT OF UNCROPPED POTS, 1908–1909

Fertilizer	Percentage of soil moisture
Complete	30 at first, gradually decreased to 15
Complete	15 throughout
Complete	30 throughout
None	15 throughout
None	30 throughout

In the cropped soil the variety of wheat used was Pringle's Champion, from Montana. The following was the arrangement of pots and the treatments received, there being duplicate pots for all treatments:

TABLE 3. TREATMENT OF CROPPED POTS, 1908–1909

Percentage of soil moisture		
First stage	Second stage	Third stage
30	30	30
30	30	15
30	15	15
15	15	15
15	15	30
15	30	15

This series was conducted for each of the three fertilizer treatments, making six pots for each moisture treatment.

On November 30, 1908, a second series, arranged as follows, was planted, to be harvested and analyzed at various stages, there being pots receiving 15 per cent and 30 per cent of moisture for each fertilizer, harvested both at boot stage and at time of bloom.

TABLE 4. TREATMENT OF SECOND SERIES OF POTS, 1908–1909

Percentage of soil moisture	Period of harvest
15	Bloom
15	Boot
30	Bloom
30	Boot

Arrangement and treatment of pots during 1909–1910

During the winter of 1909–1910 the treatments were as follows. The variety of wheat used was Galgalos, and it was planted on October 16, 1909.

TABLE 5. TREATMENT OF UNCROPPED POTS, 1909–1910

Fertilizer	Percentage of soil moisture
None	30 throughout
None	15 throughout
Complete	30 throughout
Complete	15 throughout
High nitrogen	30 throughout
High nitrogen	15 throughout
None	11 throughout
None	13 throughout
None	20 throughout
None	25 throughout
None	37½ throughout
None	45 throughout

TABLE 6. TREATMENT OF CROPPED POTS, 1909–1910

Fertilizer	Percentage of soil moisture
None	11 throughout
None	13 throughout
None	20 throughout
None	25 throughout
None	37½ throughout
None	45 throughout

As in 1908–1909, the following moisture treatments in duplicate were conducted for each of the fertilizer conditions:

TABLE 7. TREATMENT OF CROPPED POTS IN DUPLICATE, 1909–1910

Percentage of soil moisture		
First stage	Second stage	Third stage
30	30	30
30	30	15
30	15	15
15	15	15
15	15	30
15	30	15

The methods of analysis and of making the various measurements will be given in connection with the results.

EFFECTS ON THE SOIL

A study was made of the soils in the cropped and the uncropped pots. These soils, having stood for a considerable time under the conditions previously described, had the following properties examined, some being studied during both years of the experiment while others were studied for but one season: (1) volume of the soil; (2) flocculation of the soil particles; (3) nitrates; (4) nitrites; (5) ammonia; (6) total water-soluble salts; (7) number of bacteria; (8) easily soluble phosphoric acid.

The method of taking soil samples was as follows: In 1908–1909 a hollow cylinder was pressed into the soil to the bottom of the pot in six or seven places, and the soil thus removed was thoroughly mixed. This method was employed in order that the root system might not be greatly disturbed. In 1909–1910, after the plants were harvested all the soil in a pot was removed and thoroughly mixed. Samples of this fresh soil were then taken for the determination of total water-soluble salts, nitrates, nitrites, and ammonia. Some of the soil was spread out to become air-dry, and was used later in determining the flocculation and the easily soluble phosphoric acid.

Volume of the soil

Each pot contained the same dry weight of soil, so that any difference in volume was due to the extra packing produced by the treatments given. The volume was determined at the close of the experiment, by getting the average depth of the soil in the pot and the diameter of the pot, and calculating from these the total volume, then deducting the volume occupied by the small inverted pot previously described.

The latter volume was obtained by water displacement. The volume is expressed in cubic centimeters.

TABLE 8. VOLUME OF CROPPED AND OF UNCROPPED SOIL WITH DIFFERENT QUANTITIES OF MOISTURE, 1909–1910

Soil moisture (percentage)	Cropped soil: Number of pots	Cropped soil: Volume of soil per pot (cubic centimeters)	Uncropped soil: Number of pots	Uncropped soil: Volume of soil per pot (cubic centimeters)	Average volume of soil for cropped and uncropped
11	2	7,500	1	8,060	7,687
13	2	7,680	1	7,920	7,760
15	6	7,535	6	7,723	7,629
20	2	7,300	1	7,850	7,483
25	2	7,470	1	7,480	7,473
30	6	6,987	6	7,463	7,225
$37\frac{1}{2}$	2	6,365	1	6,610	6,447
45	2	6,220	1	6,130	6,190
Total	24	....	18	....	....
Average	....	7,175	....	7,509	....

From the table it is clear that the cropped soil became more compact than did the uncropped soil, and that the volume decreased as the wetness of the soil increased. It is not easy to see why the cropped soil should occupy less space than the uncropped. The explanation may be found in the fact that the cropped soil had water added to it much oftener than did the uncropped, and each addition of water tended to pack the soil somewhat. It is rather surprising that the difference in volume between the wet and the dry soil should be so great, especially since they had about eight months in which to settle.

TABLE 9. EFFECT OF FERTILIZERS ON VOLUME OF CROPPED SOIL. AVERAGE FOR ALL MOISTURE TREATMENTS. 1909–1910

Fertilizer	Number of pots	Average volume of soil in each pot (cubic centimeters)
None	12	7,388
Complete	12	7,272
High nitrogen	12	7,110

The fertilized soil, and especially that with high nitrogen, was more compact than the unfertilized. A possible explanation of this is that the fertilized soil, by producing larger crops, required more water to be added each time, and this greater quantity of water packed the soil more. Another possible cause is the deflocculating action that sodium nitrate in large quantity has been shown to exert on heavy soil. The fact that the pots receiving the heavier application of nitrate contained the most compact soil would indicate that the quantity of the nitrate was a factor.

TABLE 10. EFFECT OF CHANGING THE MOISTURE CONTENT AT DIFFERENT STAGES OF PLANT GROWTH ON THE VOLUME OF CROPPED SOIL. AVERAGE FOR ALL FERTILIZER TREATMENTS. 1909–1910

Percentage of soil moisture			Number of pots	Average volume of soil per pot (cubic centimeters)
First stage	Second stage	Third stage		
30	30	30	6	6,987
30	30	15	6	7,122
30	15	15	6	7,273
15	15	15	6	7,535
15	15	30	6	7,432
15	30	15	6	7,192

The soil continually wet was the most compact, and that continually dry was the least compact. Where it was wet for two periods it was more compact than where it was wet for but one period; and being wet during a period when the plants were young had a greater compacting effect than being wet for the same length of time when the plants were old.

Flocculation of the soil particles

In order to determine the amount of flocculation of their particles, some of the soils used during 1909–1910 were tested by the suspension method, as follows: Ten grams of air-dry soil was weighed out into an evaporating dish. Twenty-five cubic centimeters of distilled water was poured over this, to wet it thoroughly, and it was allowed to stand for a few minutes. The wet soil was washed into a glass cylinder and made up to 600 cubic centimeters with distilled water. The mouth of the cylinder was covered with the hand, and the cylinder was shaken vigorously a number of times and was then allowed to stand for one hour. Fifty cubic centimeters of the water with its suspended soil was pipetted off, the tip of the pipette being placed 25 centi-

meters from the bottom of the cylinder. This soil was evaporated to dryness in a weighed platinum dish, was weighed, and the amount of suspended soil was determined by subtracting. The soluble matter would also be present, but the amount would be so small compared to the suspended matter that it would be negligible. Of course, the greater the flocculation of particles, the less is the suspended matter.

The results showed that flocculation decreases as the moisture increases, and it was especially small in the very wet soil. There was but very little difference in the soils with small or medium quantities of moisture; indeed, the 20 per cent moisture seemed, on the whole, about the most favorable to flocculation. There was much better flocculation in the cropped than in the uncropped soil. The crop increased flocculation to the greatest extent on the very wet soil. This shows that when a soil is very wet its physical condition is likely to be much better if a crop is grown on it than if it is allowed to lie bare.

Nitrates

Nitrates, nitrites, and ammonia were determined by the method described by Schreiner and Failyer (1906). One hundred grams of soil was stirred with 500 cubic centimeters of distilled water for three minutes and allowed to stand for twenty minutes. It was then filtered through Chamberlain-Pasteur filters under pressure, and 50 cubic centimeters of the filtrate was taken for the determination of the nitrates. Portions of this same filtrate were also used for the determination of nitrites, ammonia, and total water-soluble salts. The nitrates are expressed in parts per million of NO_3 on the basis of dry soil.

TABLE 11. EFFECT OF FERTILIZERS AND OF HIGH AND LOW SOIL MOISTURE ON NITRATES IN CROPPED AND IN UNCROPPED SOIL. RESULTS FOR TWO YEARS

Fertilizer	Nitrates (in parts per million of dry soil)							
	1908–1909				1909–1910			
	Cropped		Uncropped		Cropped		Uncropped	
	30 per cent moisture	15 per cent moisture	30 per cent moisture	15 per cent moisture	30 per cent moisture	15 per cent moisture	30 per cent moisture	15 per cent moisture
None..........	2.9	32.1	296	15.2	17	10	233	177
Complete.......	2.8	35.6	396	35.1	33	9	286	269
High nitrogen.....	3.4	131.4	....	.....	27	32	399	428

The very striking thing shown in this table is the way in which the nitrates are kept down by the crop. With high nitrogen fertilizer and 15 per cent moisture during 1908–1909, there was a very poor crop and the nitrates in the soil ran high. On the uncropped soil the nitrates were usually higher with 30 per cent moisture than with 15 per cent. This was probably due to the fact that the larger crop on the wetter soil took up the excess of nitrates. The fertilized soils had more nitrates than did the unfertilized ones, due, no doubt, to nitrates added in the fertilizer.

TABLE 12. EFFECT OF DIFFERENT SOIL MOISTURE CONTENTS ON NITRATES IN CROPPED AND IN UNCROPPED SOIL. NO FERTILIZER. 1909–1910

Soil moisture (percentage)	Nitrates (in parts per million)	
	Cropped	Uncropped
11	38	Lost
13	21	188
15	10	177
20	19	156
25	23	195
30	17	233
37½	29	193
45	Trace	3
Average	20	164

Here again the effect of the crop in reducing the nitrates is very marked. All quantities of moisture below 25 per cent seemed to affect nitrification in about the same manner. Thirty per cent was the most favorable for nitrification, while 37½ per cent was decidedly inferior; and with 45 per cent there was actual denitrification, since the soil contained 36 parts per million nitrates when put in the pots. The soil with 45 per cent water was completely saturated, and when removed from the pots it had a bluish, mottled appearance and a strong odor of putrefaction, showing a lack of aeration. Notwithstanding the fact that the larger crops on the more moist soils removed more nitrates than were removed by crops on the drier soils, still nitrification seemed to keep pace with the more rapid removal.

Further data regarding nitrates in cropped soil will be given in connection with the total soluble salts.

Nitrites

None of the soil solutions contained more than merely a trace of nitrites, and the quantity present in soils under the conditions of the experiment

is certainly too small to be of any great importance; but the delicacy of the method of determination allowed a few interesting points to be brought out.

It was shown that the cropped soils were in most cases almost free from nitrites, while most of the uncropped soils had very appreciable quantities. The wettest soil, which contained very low nitrates, had the most nitrites. Other data for nitrites are found in connection with the total soluble salts.

Ammonia

The quantity of ammonia in the water extract was small and did not seem to be so much affected by the treatment as were the other constituents. A small quantity of ammonia was usually present, but it was never very much.

The striking feature about the results was the fact that ammonia was always higher in the cropped than in the uncropped soil. This is just opposite to the conditions with nitrates, nitrites, total water-soluble salts, and easily soluble phosphoric acid. The quantity of ammonia in the soil did not seem to be greatly affected by the soil moisture. It was always greater, however, with $37\frac{1}{2}$ per cent than with any other humidity.

Total water-soluble salts

The total soluble salts in the water extract mentioned above were determined by means of the electrical resistance method used by King and by the United States Bureau of Soils, and described in Bulletin No 61 of that bureau. This method, of course, gives only the electrolytes present, but these electrolytes comprise most of the material dissolved from soils by water.

TABLE 13. EFFECT OF FERTILIZERS AND OF HIGH AND LOW MOISTURE ON THE TOTAL SOLUBLE SALTS IN CROPPED AND UNCROPPED SOILS. RESULTS FOR TWO YEARS

Fertilizer	Total soluble salts (in parts per million of dry soil)							
	1908–1909				1909–1910			
	Cropped		Uncropped		Cropped		Uncropped	
	30 per cent moisture	15 per cent moisture	30 per cent moisture	15 per cent moisture	30 per cent moisture	15 per cent moisture	30 per cent moisture	15 per cent moisture
None	101	128	447	254	97	86	360	296
Complete	94	234	652	580	148	110	431	468
High nitrogen	193	489	.....	.....	122	150	662	635

The effect of the crop was to reduce the total soluble salts, but in a less degree than it reduced the nitrates. The fertilized soils gave more soluble salts than did the unfertilized, and where there was a crop the high nitrogen fertilizer was more effective in this regard than the complete fertilizer. The relation between the soluble salts in the moist and in the dry soils usually seemed to be different where there was a high nitrogen fertilizer present from what it was under the other conditions, the wet soil having more salts in one case and the dry having more in the other.

TABLE 14. TOTAL SOLUBLE SALTS, AND RATIO OF SOLUBLE SALTS TO NITRATES, IN CROPPED AND IN UNCROPPED SOIL WITH DIFFERENT MOISTURE CONTENTS. NO FERTILIZER. 1909–1910

Soil moisture (percentage)	Total soluble salts (in parts per million of dry soil)		Ratio of total soluble salts to nitrates	
	Cropped soil	Uncropped soil	Cropped soil	Uncropped soil
11	109	309	2.9 : 1	....
13	83	258	4 0 : 1	1.4 : 1
15	86	296	8.6 : 1	1.7 : 1
20	85	267	4.5 : 1	1.7 : 1
25	88	270	3.8 : 1	1.4 : 1
30	97	360	5.7 : 1	1.5 : 1
37½	95	253	3.3 : 1	1.3 : 1
45	95	100	95 0 : 1	33.3 : 1
Average	92	264	4.6 : 1	1.6 : 1

The relations shown between the cropped and the uncropped soil are similar in Table 14 to what they were in the previous table. The soil with 30 per cent moisture contained the most salts, while that with 45 per cent had the least, where there was no crop. The soil with 11 per cent moisture — both cropped and uncropped — had more salts than did the soil with medium moisture.

The ratio between soluble salts and nitrates shows some very interesting relations. The nitrates were always proportionately lower in the cropped soils, which fact shows that plants take up the nitrates proportionately faster than the other soluble salts. The low relative amount of nitrates in the very wet soil shows that the excess of water interfered with nitrification more than with the making soluble of other salts.

The nitrates were influenced much more by changing the moisture than were the other constituents. Where the moisture had been high

and was lowered, the nitrates were lower than where it was raised or where it was kept constantly high or low. This lower amount in one case may, however, be due entirely to the crop on the soil.

TABLE 15. Effect of High and of Low Soil Moisture during Different Periods on Nitrates, Ammonia, and Total Soluble Salts in Cropped Soil. Average for All Fertilizer Treatments. 1909–1910

Percentage of soil moisture			Number of pots	Parts per million			Ratio of soluble salts to nitrates
First stage	Second stage	Third stage		Nitrates	Ammonia	Total soluble salts	
30	30	30	6	27	1.37	122	4.5:1
30	30	15	6	9	1.27	102	11.3:1
30	15	15	6	24	1.28	116	4.8:1
15	15	15	6	32	1.24	115	3 6:1
15	15	30	6	27	1.57	115	4.3:1
15	30	15	6	13	1 15	108	8.3:1

TABLE 16. Effect of Fertilizers on Nitrates, Ammonia, Nitrites, and Total Soluble Salts in Cropped and in Uncropped Soils. 1909–1910

Fertilizer	Number of pots	Parts per million				Ratio of soluble salts to nitrates
		Nitrates	Ammonia	Nitrites	Total soluble salts	
Cropped soil						
None.......	12	12	1.26	....	88	7.3:1
Complete....	12	16	1.28	....	121	7.6:1
High nitrogen	12	33	1.40	....	130	3.9:1
Uncropped soil						
None.......	4	205	.81	.038	328	1.6:1
Complete....	4	278	.82	.034	450	1.6:1
High nitrogen	4	414	1.68	.157	649	1.6:1

The nitrates, ammonia, nitrites, and total soluble salts were all highest in the soil receiving the high nitrogen fertilizer. This condition held for both the cropped and the uncropped soil. As stated previously, the ammonia is the only constituent determined that was higher in the cropped than in the uncropped soil, but in this table the condition does not hold for the soil with high nitrogen. Where there was a crop the ratio of total salts to nitrates was much less with the high nitrogen fertilizer. This, of course, is what would be expected. On the soil without a crop

the ratio of total salts to nitrates did not seem to be affected to any extent by the fertilizers. There appeared to be a sort of equilibrium established between the two, with about 1.6 total salts to 1 unit of nitrates. When there were plants on the soil, however, proportionately more of the nitrates were taken up, with the effect that the ratio was widened.

Number of bacteria[3]

Samples of soil were taken from eight of the uncropped pots which had stood in the greenhouse with a constant moisture content for about eight months, and a count of the bacteria was made. The following methods were used in obtaining the counts:

The soil was sampled by pushing a hollow cylinder down to the bottom of the pot, and then removing the cylinder with the soil. This was done in five or six places in each pot, and the soil was thoroughly mixed in the laboratory by sifting. Sterile water and sterile flasks were prepared, and 0.5 gram of the mixed soil was added to 100 cubic centimeters of water and vigorously shaken for two minutes; then the contents of the flask were whirled in motion, and 1 cubic centimeter of the suspension was removed with a sterile pipette while the liquid was in rapid action. This 1 cubic centimeter was again diluted to 100 cubic centimeters with sterile water, making a strength such that 1 cubic centimeter represented $\frac{1}{20,000}$ gram of soil. During all this process care was taken to prevent air infection. One cubic centimeter of the last-mentioned dilution was added to each petri dish, and 10 cubic centimeters of the melted gelatin medium was added and was mixed with the suspension by tilting the dish backward and forward for some time. The following medium was used: dextrose 1 gram, gelatin 120 grams, soil extract 200 cubic centimeters, and water to make 1000 cubic centimeters. Reaction, 5 per cent acid. The soil extract for the medium was made as follows: 5 kilograms of soil, previously sterilized for one hour at two atmospheres pressure, was diluted with 10 liters of water and allowed to stand over night. This was boiled for one hour, the amount of water replaced, then filtered, and the filtrate was used as the soil extract in the medium.

Six petri dishes were used for each soil. The plates were allowed to incubate for seven days at a temperature of 19° to 20° C., and the number of colonies were then counted and the counts reduced to a basis of the dry soil. The number of bacteria varied from 1,750,000 to 5,000,000 for each gram of soil.

It was rather difficult to draw any conclusions regarding the effect of the treatments on the number of bacteria. It seemed, however, that the number was slightly higher with 15 per cent than with 30 per cent moisture;

[3] The author is indebted to his associate, Dr. H. J. Conn, for the bacteria counts.

also, the fertilizer seemed to have a slightly depressing effect. The differences, however, were not great enough to justify any conclusions.

Easily soluble phosphoric acid

It was thought desirable to determine the easily soluble phosphoric acid in the cropped and the uncropped soils that had stood for nearly a year with different moisture contents and different fertilizers.

The soil was removed from the pots and thoroughly mixed, and large samples were taken and air-dried. This air-dry soil remained in glass jars for a number of months before the determinations were made.

The extract of the soil was made according to the official methods of the Association of Official Agricultural Chemists for the "more active forms of phosphoric acid." That is, 2000 grams of the air-dry soil was digested for five hours at 40° C. with N/5 HCl, corrected for the amount neutralized by the soil, was filtered, and 1000 cubic centimeters was evaporated to dryness, after the addition of a few drops of HNO_3. This mass was moistened with HCl, taken up with water, filtered, and the P_2O_5 in the filtrate was determined volumetrically according to the method described by Williams (1895), the precipitation with molybdate solution being made twice. All determinations were made in duplicate.

TABLE 17. EASILY SOLUBLE PHOSPHORIC ACID IN CROPPED AND IN UNCROPPED SOILS WITH DIFFERENT MOISTURE CONTENTS. 1909–1910

Soil moisture (percentage)	Cropped soil		Uncropped soil	
	Number of pots	P_2O_5 (in parts per million of dry soil)	Number of pots	P_2O_5 (in parts per million of dry soil)
11	2	64	1	97
13	2	100	1	117
20	2	105	1	113
25	2	81	1	114
37½	2	78	1	96
45	2	110	1	116
Average	....	90	....	109

From the table it is seen that in every case the easily soluble phosphoric acid was higher on the uncropped than on the cropped soil with the same percentage of moisture, the average for the cropped soil being 90 parts per million and that for the uncropped 109 parts per million.

The quantity of phosphoric acid dissolved was quite different for various moisture treatments, but it did not vary regularly with the moisture. The lowest moisture gave the lowest phosphoric acid; then as the moisture rose there was an increase; with $37\frac{1}{2}$ per cent moisture the phosphoric acid was again low, but it rose again with 45 per cent moisture. The results appear rather strange, but the fact that the cropped and the uncropped soils agree so well makes them significant.

TABLE 18. EASILY SOLUBLE PHOSPHORIC ACID IN UNCROPPED SOIL WITH HIGH AND LOW MOISTURE AND WITH DIFFERENT FERTILIZERS. 1909–1910

Soil moisture (percentage)	P_2O_5 (in parts per million of dry soil)		
	No fertilizer	Complete fertilizer	High nitrogen fertilizer
30	81	136	116
15	82	123	117
Average	82	130	117

There seemed to be but little difference in the phosphoric acid whether the soil was kept at 30 per cent or at 15 per cent moisture, but the fertilizers applied gave marked differences. On the unfertilized soils the phosphoric acid was decidedly lower than where fertilizers were applied, and the complete fertilizer gave higher results than did high nitrogen. It is difficult to see the reason for this last condition, since there was as much phosphate applied with the high nitrogen as with the complete fertilizer; and why merely an excess of nitrate should diminish the phosphate dissolved is not clear.

EFFECTS ON THE GROWTH AND MORPHOLOGY OF WHEAT

Length of periods of growth

A record was kept of the following periods of growth in the life of the plants under different treatments: (1) number of days from planting to heading; (2) number of days from heading to maturity; (3) number of days from planting to maturity; (4) duration of the period of heading, from the time when the first head appeared in a pot until the last head was visible.

The method of obtaining these data accurately was as follows: When the plants began to head they were examined carefully every day. The

heads that had appeared since the last examination were marked and the date was recorded; when the heading of any pot was complete, the sum of the total days from the time of planting until each head appeared was divided by the number of heads. This gave the average for each pot. The period of ripening was obtained in the same way, and from these data the results given below were calculated. The period of ripening was not determined during 1908–1909.

TABLE 19. EFFECT OF HIGH AND OF LOW MOISTURE AT DIFFERENT STAGES OF GROWTH ON THE LENGTH OF THE VARIOUS GROWING PERIODS IN WHEAT. AVERAGE FOR ALL FERTILIZER TREATMENTS. RESULTS FOR TWO YEARS

Number of pots	Percentage of soil moisture			Average number of days from planting to heading		Days from heading to maturity, 1909–1910	Days from planting to maturity, 1909–1910	Duration of heading period (days)	
	First stage	Second stage	Third stage	1908–1909	1909–1910			1908–1909	1909–1910
6	30	30	30	173.3	161.0	47.3	208.3	18.7	19.3
6	30	30	15	172.7	160.6	44.7	205.3	20.0	21.0
6	30	15	15	170.0	157.0	47.0	204.0	18.3	21.7
6	15	15	15	182.3	164.0	48.3	212.3	22.0	20.0
6	15	15	30	180.0	161.3	53.4	214.7	31.0	21.7
6	15	30	15	176.7	162.0	45.7	207.7	17.7	19.3

On examining the number of days from planting to heading, it will be seen that this period was longer in every case during 1908–1909 than during 1909–1910. The plants receiving low moisture all the time were slowest to head, while those receiving high moisture up to the five-leaf stage, and low moisture all the time after that stage, were first to head during both years. Lowering the moisture at the end of the first stage hastened heading more than did lowering it at any other time or keeping it high. Raising the moisture from low to high at the five-leaf stage hastened heading somewhat, even though the moisture was again lowered at the boot stage.

The period from heading to maturity was not so much affected by the change in moisture as was that from planting to heading. However, changing the soil moisture from high to low at the boot stage cut this period short, while changing it from low to high at the same time decidedly lengthened the period.

When the total time from planting to maturity is considered, nearly the same relation is seen to exist as in the period from planting to heading. One very noticeable difference, however, is seen in the pots that had received 15 per cent moisture up to the end of the second period but were given 30 per cent during the third period. The effect of this additional water seems to have been to hasten heading slightly, but to retard ripen-

ing — as if the plants had gained a new lease on life and desired to store up more material before completing their life's work. Even at this late stage the plants sent out new shoots and became decidedly greener than those that remained dry. A difference of more than ten days will be seen in the period of ripening of two treatments, depending entirely on when they received their high moisture. Both received 15 per cent moisture during two periods and 30 per cent during one; but high moisture at first and low later hastened maturity, while the reverse condition retarded it.

In regard to the duration of heading, or the length of time after heading began in a pot until it was completed, there was much greater variation during 1908–1909 than during 1909–1910. However, the difference between the years is more quantitative than qualitative. When the moisture was raised at the boot stage the period of heading was longest; and when it had been high during the second stage but was lowered at the beginning of the third stage, heading did not continue so long. This is exactly what might be expected.

TABLE 20. EFFECT OF DIFFERENT SOIL MOISTURE CONTENTS ON THE LENGTH OF THE VARIOUS GROWING PERIODS IN WHEAT. UNFERTILIZED SOIL. 1909–1910

Number of pots	Soil moisture (percentage)	Days from planting to heading	Days from heading to maturity	Days from planting to maturity	Duration of heading period (days)
2	11	175	49	224	22
2	13	170	51	221	19
2	20	159	49	208	19
2	25	159	50	209	18
2	37½	166	48	214	21
2	45	179	45	224	25

On examining Table 20 it is seen that the very dry as well as the very wet soil increased all the periods of growth over the soil of medium moisture except the period from heading to maturity. The plants receiving 20 per cent moisture headed twenty days earlier than those receiving 45 per cent, and the duration of the heading period was six days less. The average date of maturity was exactly the same for 11 per cent moisture (which was as dry a soil as would allow the plants to grow) as for 45 per cent (when the soil was completely saturated, with considerable free water in the bottom of the pot).

The results given in Table 21 show that fertilizers hastened the time of heading, the complete fertilizer usually being more effective than

TABLE 21. EFFECT OF FERTILIZERS ON THE LENGTH OF THE VARIOUS PERIODS OF GROWTH IN WHEAT. AVERAGES FOR ALL MOISTURE TREATMENTS. RESULTS FOR TWO YEARS

Fertilizer	Number of pots	Days from planting to heading		Days from heading to maturity	Days from planting to maturity	Duration of heading period (days)	
		1908–1909	1909–1910	1909–1910	1909–1910	1908–1909	1909–1910
None........	12	179.7	167	47.3	214.3	19 5	20.1
Complete....	12	172.7	158	47.5	205 5	20.2	20.8
High nitrogen.	12	175 1	158	49.1	207.1	24.2	20.5

high nitrogen. The same relation exists with the total period of growth. Where no fertilizers were added, the plants matured nine days later than with complete fertilizer and seven days later than with high nitrogen. The duration of the heading period was always lengthened by the fertilizers. The general conclusion might be drawn that an evenly balanced fertilizer tended to make the plants mature in the shortest time, and even a high nitrogen fertilizer made the period shorter than where no fertilizer was applied.

Tillering

Counts were made at various periods during the growth of the plants, in order to determine the amount of tillering, or stooling. It will be remembered that there were originally but twelve plants in each pot, so that any above this number resulted from branching, or tillering. Of course most of the branching was at the base of the culm, but there was also considerable tendency for the culm to branch at the top node, thus producing two or three heads on one culm. This was especially true during 1908–1909 and with certain treatments.

In Tables 22 and 23 it is shown how the number of tillers varied as the plants grew.

In Table 22 it is seen that there were always more tillers with 30 per cent than with 15 per cent soil moisture; also that, as a rule, the fertilized pots, and especially those with high nitrogen, had more tillers than did the unfertilized pots.

In comparing the seasons, the crop grown during 1909–1910 tillered more with every treatment than did that grown during 1908–1909. This may be due in part to the different conditions during the two years; but it is more probably due mainly to the variety of wheat, Pringle's Champion tillering less than Galgalos.

TABLE 22. NUMBER OF TILLERS AT VARIOUS STAGES WITH DIFFERENT FERTILIZERS AND WITH HIGH AND LOW MOISTURE. RESULTS FOR TWO YEARS

Soil moisture (percentage)	Fertilizer	Average number of tillers per pot					
		1908–1909			1909–1910		
		First stage	Second stage	Number of heads at maturity	First stage	Second stage	Number of heads at maturity
30	None	29.6	13.5	15.5	39.5	15.5	16.5
15	None	12.0	12.0	12.0	19.5	13.5	13.5
30	Complete	39.6	17.0	19.0	43.0	21.5	22.0
15	Complete	18.2	12.0	12.0	29 5	16.0	16.5
30	High nitrogen	42.6	17.0	19.0	45.0	23.5	26.5
15	High nitrogen	14 2	11 5	13.0	31.5	15.5	15.0

TABLE 23. NUMBER OF TILLERS AT VARIOUS STAGES WITH WIDELY VARYING SOIL MOISTURE. NO FERTILIZER. 1909–1910

Soil moisture (percentage)	Average number of tillers per pot		
	First stage	Second stage	Number of heads at maturity
11	13 0	12 0	12.0
13	15 0	12 0	12.0
15	19.5	13 5	13.5
20	17.5	12.0	12.5
25	24.0	14.5	14.5
30	39.5	15 5	16.5
37½	33.0	18.0	18.5
45	31.0	22.5	20.0

With some of the treatments there were more than twice as many tillers at the five-leaf stage as at the boot stage, the others having died. This falling off in the number of tillers was greater with the higher percentage of moisture.

What seems to be a rather peculiar condition is that actually more heads were produced than were tillered at the boot stage. This was due to a branching of the culm at the top node, and the production of secondary heads which usually matured somewhat later than the first heads.

In Table 23 it will be noticed that 30 per cent moisture produced the most tillers at first, but that 45 per cent moisture gave the most heads

at maturity. With the low amounts of moisture there was scarcely any stooling. The relation between the periods is similar to that found in Table 22.

TABLE 24. EFFECT OF HIGH AND OF LOW MOISTURE AT DIFFERENT STAGES ON THE NUMBER OF HEADS OF WHEAT PRODUCED PER POT. AVERAGE FOR ALL FERTILIZER TREATMENTS. RESULTS FOR TWO YEARS

Number of pots	Percentage of soil moisture			Average number of heads per pot	
	First stage	Second stage	Third stage	1908–1909	1909–1910
6	30	30	30	17.8	21.7
6	30	30	15	15.7	20.7
6	30	15	15	14.2	17.8
6	15	15	15	12.3	15.0
6	15	15	30	14.3	15.7
6	15	30	15	13.8	18.2

The fact previously noted, that more tillers were produced during 1909–1910 than during 1908–1909 is shown also in this table. The greatest number of heads was produced when there was 30 per cent moisture throughout the entire growth of the plants, and the least number when there was 15 per cent all the time. Raising the moisture during any period increased the number of heads, while lowering it at any time had the opposite effect.

TABLE 25. EFFECT OF FERTILIZERS ON THE NUMBER OF HEADS PER POT. AVERAGE FOR ALL MOISTURE TREATMENTS. RESULTS FOR TWO YEARS

Fertilizer	Number of pots	Average number of heads per pot	
		1908–1909	1909–1910
None	12	13.3	15.1
Complete	12	15.1	19.4
High nitrogen	12	15.7	20.0

This summary table shows what has been previously noted; namely, that the fertilizers, and especially those with high nitrogen, increased tillering and the production of heads.

Miscellaneous observations and measurements during growth

General observations.— Within two or three weeks after the plants were up, they began to show distinct response to the fertilizers and moisture.

Those with 30 per cent moisture showed a darker color, broader leaves, and a more thrifty appearance generally, than those with 15 per cent. The fertilized plants showed similar advantages over the unfertilized ones.

When the soil moisture was changed from 30 per cent to 15 per cent in the pots at any stage, the plants very soon lost their turgor and looked wilted, and it was a number of weeks before they seemed to regain equilibrium. They also became covered with a white waxy bloom, so that the plants receiving this treatment could be readily distinguished from the others. All the plants took on this bloom, to an extent, later.

In the pots in which the moisture content was changed from 15 to 30 per cent at the end of the first or the second stage, an increased vigor of growth was noticeable within a week or two. This newer, rapid growth was lighter in color than the old, slower growth.

During most of the life of the wheat plants there were but five green leaves at a time on each culm. As fast as a new leaf was formed an old one died. The treatment affected the rate at which the new leaves were formed; but the number of green leaves was practically constant until the plants approached maturity, when the number was reduced. The plants in the drier soil remained green longer than did those in the wet soil.

Mildew, which attacked the plants from time to time, seemed to be severer on the plants with high moisture, and especially on those with high nitrogen fertilizer. The plants with 30 per cent moisture and with high nitrogen also had weaker culms than did those receiving other treatments, and when the supports were removed these plants were unable to support their own weight.

Until the end of the first month the plants in the soil with 45 per cent moisture were the tallest; after that they fell behind those in the soil with $37\frac{1}{2}$ per cent moisture. These in turn remained the tallest for about two months, when even they fell behind those on the soil with 25 per cent moisture. Thus the plants did not respond in the same relation to soil moisture during all periods of growth. They seemed able to endure more moisture during early periods than later.

Measurements at the end of the first period.— The relative heights of plants with different treatments is shown in Table 26.

The striking fact shown in Table 26 is that with the variety of wheat grown in 1909–1910 the height was not so much affected by the various treatments as with the variety grown in 1908–1909. However, the weight of dry matter at maturity showed the effects much more than the above measurements would indicate.

Measurements at the end of the second period.— The relative size of the plants at the boot stage is brought out in Tables 27 and 28.

TABLE 26. EFFECT OF MOISTURE AND OF FERTILIZERS ON HEIGHT OF WHEAT PLANTS AT THE FIVE-LEAF STAGE. RESULTS FOR TWO YEARS

Fertilizer	Soil moisture (percentage)	Number of pots	Average height of plants (inches)	
			1908–1909	1909–1910
None	30	6	17.0	10.5
None	15	6	7.5	8.5
Complete	30	6	22.0	13.0
Complete	15	6	14.0	10.0
High nitrogen	30	6	24.0	13.0
High nitrogen	15	6	16.0	11.0

TABLE 27. EFFECT OF MOISTURE AND OF FERTILIZERS ON THE HEIGHT, LEAF LENGTH, AND LEAF WIDTH OF WHEAT PLANTS AT THE BOOT STAGE. RESULTS FOR TWO YEARS

Percentage of soil moisture		Fertilizer	Number of tops	Average height to base of top leaf (inches)		Average length of second leaf from top (inches)		Average width of second leaf from top (centimeters)	
First stage	Second stage			1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910
30	30	None	4	19.0	11.5	11.5	7.0	1.2	0.9
30	15	None	2	18.0	11.0	10.0	5.0	1.1	0.9
15	15	None	4	8.5	11.0	9.0	7.5	0.6	0.8
15	30	None	2	12.0	13.0	12.0	10.0	1.1	0.9
30	30	Complete	4	24.5	22.0	12.0	8.5	1.2	1.0
30	15	Complete	2	24.0	20.0	10.5	8.0	1.2	0.9
15	15	Complete	4	15.0	15.0	10.0	8.0	0.9	0.9
15	30	Complete	2	21.0	21.0	14.5	9.0	1.2	1.0
30	30	High nitrogen	4	29.0	25.5	13.0	11.0	1.3	1.1
30	15	High nitrogen	2	24.0	23.0	11.0	9.0	1.1	1.0
15	15	High nitrogen	4	13.0	18.0	10.5	9.0	0.9	0.9
15	30	High nitrogen	2	24.0	20.0	15.5	12.0	1.4	1.0

On examining Table 27 it is seen that the measurements for height at the end of the second period continued in about the same relation as those shown in Table 26 for the first stage. The differences between the treatments, however, are not so marked. When the moisture was lowered from 30 to 15 per cent at the end of the first period, the height, the leaf length, and the leaf width were all lessened in comparison to the plants receiving 30 per cent during both periods. When the moisture was raised from 15 to 30 per cent at this stage, however, there was a decided increase in all these measurements, the leaf length being the most affected. In every case a longer leaf was produced by this treatment than by any

TABLE 28. Effect of a Wide Range of Soil Moisture on the Height, Leaf Length, and Leaf Width of Wheat Plants at the Boot Stage. 1909–1910

Soil moisture (percentage)	Average height to base of top leaf (inches)	Average length of second leaf from top (inches)	Average width of second leaf from top (centimeters)
11	9	7	0.6
13	10	8	0.7
20	15	9	0.8
25	18	8	0.9
37½	17	9	1.0
45	11	8	0.7

other. It will be noted that when the moisture was low during both periods, the width of the leaves was especially small.

The degree to which the extremes of moisture affected the various measurements is shown in Table 28. At the boot stage the highest plants were those receiving 25 per cent moisture; while the very moist, as well as the very dry, soil produced shorter plants. The length of leaf was not so much affected as was the width, which was nearly twice as great with 37½ per cent moisture as with the very dry soil. The plants grown with 45 per cent moisture were about the same size as those with but 13 per cent, while during the first month of growth they were better than the plants with any other treatment.

Morphology at maturity

At the time of harvest detailed measurements were made, and these are summarized in the tables that follow.

TABLE 29. Effect of Different Soil Moisture Contents on the Number of Nodes per Culm, Length of Culm, Length of Head, and Ratio of Culm Length to Head Length. No Fertilizer. 1909–1910

Soil moisture (percentage)	Number of pots	Average number of nodes per culm	Average length of culm (inches)	Average length of head (inches)	Ratio of culm length to head length
11	2	3.8	16.7	1.45	11.5:1
13	2	3.7	18.9	1.60	11.8:1
20	2	3.5	26.4	2.25	11.7:1
25	2	3.8	29.2	2.20	13.3:1
37½	2	4.1	31.1	2.30	13.5:1
45	2	4.4	22.8	1.75	13.0:1

The very wet soil produced culms with the greatest number of nodes, while the medium degree of moisture produced the least number of nodes.

The largest culms and heads were produced with 37½ per cent moisture, while with 45 per cent the culms and heads were shorter than in any other except the very dry soil. Thus, similarly to too little moisture, too much moisture retarded the growth. When the ratio of the culm length to the head length is examined, it is seen that the drier soils produced proportionately longer heads than did the moist soils.

The number of nodes per culm does not vary greatly with changes in moisture; but, as is seen in Table 30, the difference between the two

TABLE 30. EFFECT OF HIGH AND OF LOW MOISTURE DURING DIFFERENT PERIODS OF GROWTH ON THE NUMBER OF NODES PER CULM, LENGTH OF CULM, LENGTH OF HEAD, AND RATIO OF CULM LENGTH TO HEAD LENGTH. AVERAGE FOR ALL FERTILIZER TREATMENTS. RESULTS FOR TWO YEARS

Percentage of soil moisture			Number of pots	Average number of nodes per culm		Average length of culm (inches)		Average length of head (inches)		Ratio of culm length to head length	
First stage	Second stage	Third stage		1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910
30	30	30	6	5.9	3 9	38.7	33.0	2.93	2.38	13.2 1	13.9:1
30	30	15	6	5.9	3 9	35.6	29.6	2.80	2.35	12 7:1	12.6:1
30	15	15	6	6.3	3.9	35.8	29.4	2.60	2.63	13.8:1	11.2:1
15	15	15	6	5.7	3.6	26.0	26.0	1.97	2.22	13.2:1	11.7:1
15	15	30	6	5.3	3.7	28.5	29.8	2.47	2.45	11.5:1	12.2:1
15	30	15	6	5.2	3.7	32.6	28.3	2.77	2.33	11.8:1	12.1:1

seasons is very marked, due, no doubt, to the variety used. The figures bring out distinctly that the number of nodes per culm is largely determined by the moisture present during the first period of growth. When there was 30 per cent moisture at first the number was always greater than when there was 15 per cent, regardless of later treatment.

The length of the culm also seemed to be more influenced by the moisture during the first period than at any other time. However, raising the moisture in any other period also increased the length, while lowering it had the opposite effect; and, in most cases, where the moisture was high during two periods, the culms were longer than where it was high during but one period.

The shortest heads were always produced where the moisture was low all the time. Raising the moisture during any period increased the length of the head.

The difference between the number of nodes per culm in the two varieties is shown distinctly in Table 31. The table brings out also the fact that the number of nodes was greater on the fertilized soil, especially where

high nitrogen was used. The length of the culms and of the heads was also greater where fertilizers were applied. The length of the heads in comparison with the culms, however, was proportionately greater in the unfertilized than in the fertilized crop.

TABLE 31. EFFECT OF FERTILIZERS ON THE NUMBER OF NODES PER CULM, LENGTH OF CULM, LENGTH OF HEAD, AND RATIO OF CULM LENGTH TO HEAD LENGTH. AVERAGE FOR ALL MOISTURE TREATMENTS. RESULTS FOR TWO YEARS

Fertilizer	Number of pots	Average number of nodes per culm		Average length of culm (inches)		Average length of head (inches)		Ratio of culm length to head length	
		1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910
None..........	12	5.5	3.5	29.8	24.8	2.43	2.13	12.3:1	11.6:1
Complete.......	12	5.7	3.9	34.7	30.1	2.75	2.40	12 6:1	12.5:1
High nitrogen...	12	6.0	3.9	34.1	33.2	2.59	2.68	13.2:1	12.4:1

Number, weight, and kind of kernels

A count was made of the kernels produced in each pot, and, since the number of heads was known, it was easy to determine the average number of kernels produced per head. The air-dry kernels were also weighed, and the weight of one hundred kernels was calculated from the total number and the total weight.

TABLE 32. EFFECT OF DIFFERENT MOISTURE CONTENTS ON THE NUMBER OF KERNELS PER POT, NUMBER OF KERNELS PER HEAD, AND WEIGHT OF 100 KERNELS. NO FERTILIZER. 1909–1910

Soil moisture (percentage)	Number of pots	Average number of kernels per pot	Average number of kernels per head	Weight of 100 kernels (grams)
11..................................	2	59	4.9	3.89
13..................................	2	68	5.7	4.09
15..................................	2	112	8.3	3.83
20..................................	2	138	11.1	3.64
25..................................	2	160	11.1	3.60
30..................................	2	148	9.0	3.88
37½.................................	2	201	10.9	3.32
45..................................	2	170	8.4	3.05

The number of kernels produced in a single pot increased with an increase in moisture up to 37½ per cent, but above that amount it decreased. The number of kernels per head was greater with a medium amount of

moisture than with very little or very much. In general, however, the low moisture produced heads containing fewer kernels than those produced by the high moisture.

As to the plumpness of grain and the weight of one hundred kernels, the results are quite different. The largest, plumpest, and heaviest kernels were produced with very low moisture, and the lightest with very high. Indeed, the kernels from the soil with 45 per cent moisture were considerably shrunken. This was not due to any cutting short of the growing period or sudden unfavorable condition at the last, for the plants had a normal maturation and a long period of growth.

An examination of the kernels showed that those grown with very low moisture were practically all flinty and hard in appearance, with a light reddish tint; and that as the moisture increased the number of flinty kernels decreased, until with 37½ per cent moisture there were no flinty kernels but all had a starchy appearance. This plumpness of kernels should be compared with the percentage of nitrogen given later.

The following table shows, in general, the most kernels, per pot as well as per head, where the moisture was high, and the least number where the moisture was low, during the entire period of growth. Where there was low moisture during two periods and high during one, it did not seem to matter greatly which period received the high moisture. During 1908–1909 the number of kernels, per pot as well as per head, was much more affected by the moisture than during 1909–1910. The number of kernels was greater during 1908–1909 than during 1909–1910, but the grain produced in the latter year was decidedly the heavier. The weight of one hundred kernels was always greater where the moisture was changed at some period than where it remained at either 30 per cent or 15 per cent all the time. The lighter kernels were associated with the higher moisture.

TABLE 33. EFFECT OF HIGH AND OF LOW MOISTURE DURING DIFFERENT PERIODS OF GROWTH ON THE NUMBER OF KERNELS PER POT, NUMBER OF KERNELS PER HEAD, AND WEIGHT OF 100 KERNELS. AVERAGE FOR ALL FERTILIZER TREATMENTS. RESULTS FOR TWO YEARS

Percentage of soil moisture			Number of pots	Average number of kernels per pot		Average number of kernels per head		Average weight of 100 kernels (grams)	
First stage	Second stage	Third stage		1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910
30	30	30	6	406	297	23	13.2	2.73	3.72
30	30	15	6	336	237	22	11.1	2.83	4.07
30	15	15	6	255	225	19	12.5	2.85	3.84
15	15	15	6	159	153	13	10.2	2.80	3.78
15	15	30	6	288	211	20	13.6	2.81	3.78
15	30	15	6	289	217	21	11.9	2.86	3.86

TABLE 34. EFFECT OF FERTILIZERS ON THE NUMBER OF KERNELS PER POT, NUMBER OF KERNELS PER HEAD, AND WEIGHT OF 100 KERNELS. AVERAGE FOR ALL MOISTURE TREATMENTS. RESULTS FOR TWO YEARS

Fertilizer	Number of pots	Average number of kernels per pots		Average number of kernels per head		Average weight of 100 kernels (grams)	
		1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910
None............	12	230	141	17	10	2.81	3 94
Complete........	12	318	230	21	12	2 84	3 82
High nitrogen.....	12	319	299	20	15	2.79	3.77

In Table 34 it is seen that the fertilized soils produced more kernels, per pot and per head, than did the unfertilized. The high nitrogen was on the average more effective in this regard than the balanced complete fertilizer. The lightest grain was produced by the high nitrogen fertilizer, and, as a rule, the heaviest grain came from the unfertilized soil.

From the results shown in the last three tables, it would appear that certain of the conditions favoring the production of but few kernels tend to produce heavy, plump grain. It seems that the wheat plant responds to unfavorable conditions by diminishing the number of kernels produced, rather than by decreasing the size and weight of the kernels.

EFFECTS ON YIELD

Dry matter produced at different stages

During the season of 1908–1909, plants were harvested at the boot and at the bloom stage as well as at maturity. The roots for all plants raised during this season were carefully weighed and analyzed. During the season of 1909–1910 no harvests were made except at maturity and no roots were washed out, since it was desired to make a more careful study of the soil.

From a study of Table 35 it is seen that the dry matter in the tops rapidly increased from the boot stage to maturity. With the high moisture there was more than twice as much at the latter period as at the former, while with low moisture the increase was not so great. In other words, proportionately more of the dry matter in the tops was produced by the boot stage in the dry soil than was produced in the wet.

The weight of roots recovered decreased from the boot stage to maturity, with all treatments. This may have been due to an actual dying and decaying of some of the roots as the plants approached maturity, or it may have been due to the fact that all the roots could not be so well

TABLE 35. EFFECT OF MOISTURE AND OF FERTILIZERS ON THE DRY WEIGHT OF TOPS AND ROOTS OF WHEAT AT VARIOUS STAGES OF GROWTH. 1908–1909

Fertilizer	Soil moisture (percentage)	Dry weight of tops (grams)			Dry weight of roots (grams)			Ratio of tops to roots		
		Boot stage	Bloom stage	Maturity	Boot stage	Bloom stage	Maturity	Boot stage	Bloom stage	Maturity
None.........	30	35.31	50.54	74.95	15.80	10.73	9.31	2 2:1	4.7:1	8.1:1
None........	15	15.21	19.38	29.28	10.02	8.82	9.59	1.5:1	2.2:1	3.1:1
Complete.....	30	45 48	76.24	102.02	22.87	14 36	11.71	2.0:1	5.3:1	8.7:1
Complete.....	15	27.79	39.96	52.32	20.76	12.46	13.19	1.3:1	3.2:1	4.0:1
High nitrogen..	30	39 69	65.97	112.12	14.13	12.65	11.45	2.8:1	6.1:1	9.8:1
High nitrogen..	15	26.50	39 47	37.78	18.29	11 40	13 19	1.4:1	3.5:1	2.9:1

recovered when the plants were older. In the unfertilized soil and in that receiving complete fertilizer, the weight of roots was greater in the moist soil at the bloom and boot stages than in the dry soil, while at maturity just the opposite was true. In the soil receiving high nitrogen, however, the dry soil contained actually more roots than the moist, notwithstanding the fact that the wet soil produced about three times as much top as did the dry soil. This is brought out when the ratio of the tops to the roots is studied.

In all treatments there were proportionately more tops as the plants matured. Likewise at all stages the relative weight of tops was greater in the moist than in the dry soil, and greater in the fertilized than in the unfertilized soil.

Dry matter at maturity

The yields of grain and of straw increased regularly with the moisture up to 37½ per cent, but at 45 per cent the yield of both, and especially that of the grain, was considerably reduced.

TABLE 36. EFFECT OF DIFFERENT SOIL MOISTURE CONTENTS ON THE DRY WEIGHT OF GRAIN AND STRAW. NO FERTILIZER. 1909–1910

Soil moisture (percentage)	Weight per pot (in grams)			
	Grain	Straw	Grain and straw	Ratio of straw to grain
11..............................	4.07	11.06	15.13	2.72:1
13..............................	4.96	12.96	17.92	2.61:1
15..............................	7.68	18.80	26.48	2.45:1
20..............................	8.97	21.15	30.12	2.36:1
25..............................	10.30	25.17	35.47	2.44:1
30..............................	10.32	26.90	37.22	2.61:1
37½..............................	13.73	34.70	48.43	2.53:1
45..............................	9.17	27.27	36.44	2.97:1

The largest relative amount of grain was produced with an intermediate soil moisture with respect to both the very dry and the very wet, the latter especially producing proportionately more straw.

TABLE 37. EFFECT OF HIGH AND OF LOW MOISTURE DURING DIFFERENT PERIODS OF GROWTH ON THE DRY WEIGHT OF GRAIN, STRAW, AND ROOTS OF WHEAT. AVERAGE FOR ALL FERTILIZER TREATMENTS. RESULTS FOR TWO YEARS

Percentage of soil moisture			Number of pots	Weight per pot (in grams)						Ratio of straw to grain		Weight of roots (grams)	Ratio of tops to roots
First stage	Second stage	Third stage		Grain		Straw		Grain and straw					
				1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1908–1909
30	30	30	6	9 94	9 80	34.94	23.23	44.88	33.03	3.5 : 1	2 4 : 1	5.41	9 1 : 1
30	30	15	6	8 55	8 68	31.98	21.39	40.53	30.07	3.7 : 1	2.5 : 1	6.76	6 1 : 1
30	15	15	6	8 24	7 69	26.40	18.74	34.64	26.43	3 2 : 1	2 4 : 1	6.06	5 9 : 1
15	15	15	6	4.14	5.17	15 75	12.88	19.89	18.05	3 8 : 1	2 5 : 1	5.99	3 3 : 1
15	15	30	6	7.25	7 06	20 66	14 96	27 91	22.02	2.8 : 1	2 1 : 1	5 73	5.0 : 1
15	30	15	6	7.38	7 47	25.81	17 97	33.19	25.44	3.5 : 1	2 4 : 1	8 58	3 8 : 1

From Table 37 it is seen that the greatest quantity of grain, as well as of straw, was always produced on the soil receiving 30 per cent moisture during the three periods, while the least quantity was produced on that receiving 15 per cent. Raising the moisture during any period increased the yield of both grain and straw, and having the moisture high during two periods increased the yield still more. The fact that the grain and the straw were not affected to the same degree by these changes in moisture is clearly brought out in the figures for ratio of straw to grain. Where the soil humidity was maintained at 30 per cent or at 15 per cent during all periods there was nearly four times as much straw as grain in 1908–1909, but raising or lowering the humidity at any time affected this ratio. The treatment giving relatively most grain was that in which the moisture was kept at 15 per cent during the first two periods but raised to 30 per cent during the third; while in the treatment giving relatively least grain the moisture was kept at 15 per cent during the entire growth of the crop. Those pots receiving high moisture at first and low moisture later always produced proportionately more straw than those receiving low moisture at first and high moisture later.

The weight of roots was least in the soil receiving 30 per cent moisture continuously, and greatest in that with 15 per cent in the first and third periods and 30 per cent in the second period.

The ratio of tops to roots was very much affected by the moisture treatment, being nearly three times as great in the moist as in the dry soil. The moisture received during early periods of growth was more important in influencing this ratio than that received later.

The effects of fertilizers on the yield of the various parts of the plant are summarized in the following table:

TABLE 38. EFFECT OF FERTILIZERS ON THE DRY WEIGHT OF GRAIN, STRAW, AND ROOTS OF WHEAT. AVERAGE FOR ALL MOISTURE TREATMENTS. RESULTS FOR TWO YEARS

Fertilizer	Number of pots	Weight per pot (in grams)						Ratio of straw to grain		Weight of roots (grams)	Ratio of tops to roots
		Grain		Straw		Grain and straw					
		1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1908–1909
None	12	5.72	4.94	20.61	12.00	26.33	16.94	3.6 : 1	2.4 : 1	5.91	4.7 : 1
Complete	12	8.06	7.85	29.84	19.11	37.90	26 96	3.7 : 1	2.4 : 1	6.53	6.1 : 1
High nitrogen	12	8 04	10.12	29.92	23.47	37.96	33 59	3.7 : 1	2 3 : 1	6.83	5.9 : 1

The fertilized soil always gave a better yield of each of the plant parts than did the unfertilized. In 1908–1909 the complete fertilizer and that with high nitrogen gave about the same yield of grain, straw, and roots; but in 1909–1910 the high nitrogen proved superior. The data are not given here in sufficient detail to bring out one point that was constantly noticed, namely, that the high nitrogen fertilizer was more efficient in the soil with high moisture than in that with low moisture.

The ratio of straw to grain was not, on the average, greatly affected by the fertilizers, but under certain moisture conditions there was a decided effect.

The actual weight of roots was greater in the fertilized pots, but compared with the tops the unfertilized soil produced more roots. These results and those previously cited show that the root growth is relatively greater in soils lacking fertility and in those containing low moisture. This is in agreement with the findings of the investigators mentioned in the summary of the literature on the subject.

EFFECTS ON TRANSPIRATION

The transpiration was accurately determined by the method previously described. Weighings were made at the same hour at the end of each week, so that the transpiration by weeks could be obtained. The results for total transpiration and the relation between water transpiration and dry matter produced will first be discussed.

Total transpiration, and relation between transpiration and dry matter produced

In Table 39 it is seen that the transpiration is least in the driest soil, that it gradually rises with the soil moisture up to 37½ per cent, and that it then falls off; and that with 45 per cent moisture the transpiration is but slightly greater than with 25 per cent. The relative economy of transpiration shown in the last two columns brings out some interesting relations. The greatest economy in the production of total dry matter was

TABLE 39. EFFECT OF DIFFERENT SOIL MOISTURE CONTENTS ON THE TOTAL WATER TRANSPIRED BY WHEAT AND ON THE AMOUNT OF WATER TRANSPIRED IN PRODUCING A UNIT OF DRY MATTER. NO FERTILIZER. 1909–1910

Soil moisture (percentage)	Number of pots	Total transpiration per pot (kilograms)	Number of grams of water transpired in producing one gram of straw and grain	Number of grams of water transpired in producing one gram of grain
11	2	5 58	737	2,743
13	2	6.78	696	2,740
20	2	11.27	739	2,690
25	2	14.37	811	2,793
37½	2	20 67	854	3,010
45	2	15.42	850	3,369

with 13 per cent soil moisture, but the grain was most economically produced with 20 per cent. Less economy is found in both cases with very high moisture. The results indicate that dry matter can be produced with the greatest economy of water on a medium dry soil, but if the soil is very dry or very wet there is more waste. This waste in water is particularly noticeable with very high moisture. A number of investigators have reported that they found no relation between soil humidity and the water required in order to produce a unit of dry weight. It is likely, however, that they did not test enough points between the high and the low moisture to show the real condition. A high and a low moisture might give the same result, while an intermediate degree would give a different result.

A study of Table 40 shows that, as might be expected, the greatest total transpiration was with the high moisture during all three periods, and the least was with the low moisture during the entire time of growth. High moisture during the second period increased the transpiration more

than during any other single period. This was doubtless due to the fact that this was the period of most rapid growth.

TABLE 40. EFFECT OF HIGH AND OF LOW SOIL MOISTURE DURING DIFFERENT PERIODS OF GROWTH ON THE TOTAL TRANSPIRATION OF WHEAT AND ON THE AMOUNT OF WATER TRANSPIRED IN PRODUCING A UNIT OF DRY MATTER. AVERAGE FOR ALL FERTILIZER TREATMENTS. RESULTS FOR TWO YEARS

Percentage of soil moisture			Number of pots	Total transpiration per pot (kilograms)		Number of grams of water transpired in producing one gram of straw and grain		Number of grams of water transpired in producing one gram of grain	
First stage	Second stage	Third stage		1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910
30	30	30	6	30.13	22.98	626	739	3,066	2,553
30	30	15	6	22.88	19.59	568	682	2,689	2,428
30	15	15	6	17.31	15.10	502	601	2,636	2,166
15	15	15	6	10.25	11.53	529	653	2,597	2,280
15	15	30	6	15.97	15.13	576	698	2,230	2,194
15	30	15	6	17.58	16.20	532	613	2,397	2,199

The greatest waste of water in the production of grain and straw, as well as of grain alone, was always in the pots receiving 30 per cent moisture during all three periods.

Considering both straw and grain, the most economical treatment was with 30 per cent moisture during the first period and 15 per cent during the last two periods. Considering grain alone, however, it was more economical to have the high moisture come later. In 1908–1909, 37 per cent more water was required in order to produce the dry matter in grain where there was high moisture continuously than where there was high moisture only during the last stage. This is certainly an important economic difference where water is the limiting factor in plant growth and where the time of application can be regulated by irrigation. The difference between these treatments was of considerable importance. These results point very strongly to the fact that the time when water is applied has a great influence on the quantity of dry matter that a given quantity of water will produce.

Fertilizers greatly increased the transpiration, and the high nitrogen caused a greater transpiration than did the complete fertilizer. This was especially the case in the presence of high moisture. The table above is not given in sufficient detail to show this fact.

When the relation between transpiration and dry matter is examined, it is seen that water was not used so economically by the unfertilized as by the fertilized soil. During the season of 1909–1910 the high nitrogen fertilizer was much more economical in its use of water than the complete

TABLE 41. EFFECT OF FERTILIZERS ON THE TOTAL TRANSPIRATION OF WHEAT AND ON THE AMOUNT OF WATER TRANSPIRED IN PRODUCING A UNIT OF DRY MATTER. AVERAGE FOR ALL MOISTURE TREATMENTS. RESULTS FOR TWO YEARS

Fertilizer	Number of pots	Total transpiration per pot (kilograms)		Number of grams of water transpired in producing one gram of straw and grain		Number of grams of water transpired in producing one gram of grain	
		1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910
None	12	15.50	13.23	583	781	2,641	2,711
Complete	12	20.58	17.22	533	634	2,522	2,186
High nitrogen	12	20 98	19 82	551	593	2,678	1,976

fertilizer, but during the previous year the result was slightly in favor of the complete fertilizer. The results all the way through indicate that a given quantity of water will produce more dry matter on a fertile than on an unfertile soil.

The above data make it very clear that a pound of dry matter in wheat does not always require the same amount of water for its production, as was believed by some of the early workers. The results of a number of investigators already referred to show that conditions modify this relation. This line of investigation, if pursued further and applied practically to regions where moisture is the chief consideration in crop production, would be of the greatest economic importance.

Transpiration during various periods of growth

The relative transpiration during the various periods of growth was determined; but, since some of this work has been presented elsewhere by the author (1911), its discussion here will be confined to a few general statements. The transpiration, small at first, gradually increased until after the plants had blossomed, when it rapidly diminished, and as maturity was approached there was scarcely any water transpired. This is shown in the curve that follows (Fig. 108). The irregularities in the transpiration in response to external conditions will be discussed later.

It was found that the quantitative relation between the transpiration for different treatments did not continue the same at all times; that is, at the end of one month the relative transpiration was not the same as at the end of two or three months or at maturity. Those wishing to investigate this question further will find it discussed in some detail in the paper just referred to.

Relation of transpiration to temperature, sunshine, and humidity

An effort was made to keep the temperature of the greenhouse between 60° and 65° F. It was impossible to do this completely, but a thermographic record was kept, so that all fluctuations are known. The relative humidity was determined daily at the same hour, and the number of hours of sunshine each day was obtained from the records of the United States Weather Bureau, taken about two hundred yards from the greenhouse. It was thus possible to determine the manner in which these factors affected the use of water by the plants.

The accompanying curve shows how the transpiration rose during the season up to a certain point, when it rapidly decreased. It also shows how fluctuations in the temperature, sunshine, and humidity affected the transpiration in the pots represented. The great falling-off in the transpiration during the two weeks preceding February 20 was doubtless due to snow, which kept the greenhouse covered and cut off a considerable amount of the light.

When the transpiration during 1908–1909 is traced through the season, the following striking results are noted:

During the week from November 21 to 28 there was a substantial increase in transpiration over the previous week in all pots containing 30 per cent water; but in those with 15 per cent water and no fertilizer there was an actual decrease below the previous week, and even where fertilizers were used the increase was not nearly so great in the plants with 15 per cent moisture as in those with 30 per cent.

During the previous week (November 14 to 21) the average temperature was 60.3°. The hours of sunshine during this week were 26.7, while during the following week there were 33.2 hours. The humidity, however, was increased to 68.7 per cent in the second week as compared with 55.2 per cent in the previous week. It appears from the above that the increased temperature and sunshine, even with higher relative humidity, greatly raised the transpiration in pots containing 30 per cent water, while this was not true of the plants grown in the drier soil.

During the week from December 12 to 19 there was a decrease in the transpiration compared with the previous week in the pots with 15 per cent water and without fertilizer. In all other pots there was an increase, it being proportionately greater in the pots with high nitrogen fertilizers. During this week the sunshine decreased to 7.6 hours, as compared with 14.2 hours during the previous week. The relative humidity also decreased from 61.8 to 56.5 per cent. The temperature, however, increased from 59.5° to 62.1°.

During the week from December 26 to January 2 all pots fell off in transpiration as compared with the previous week, the pots with 15

per cent moisture decreasing 25 per cent to 40 per cent, while those with 30 per cent had a decrease of only 3 per cent to 10 per cent. Comparing the two weeks in order, we have the temperature 60.6° and 59.6°, the relative humidity 63.7 and 64, and the total hours of sunshine

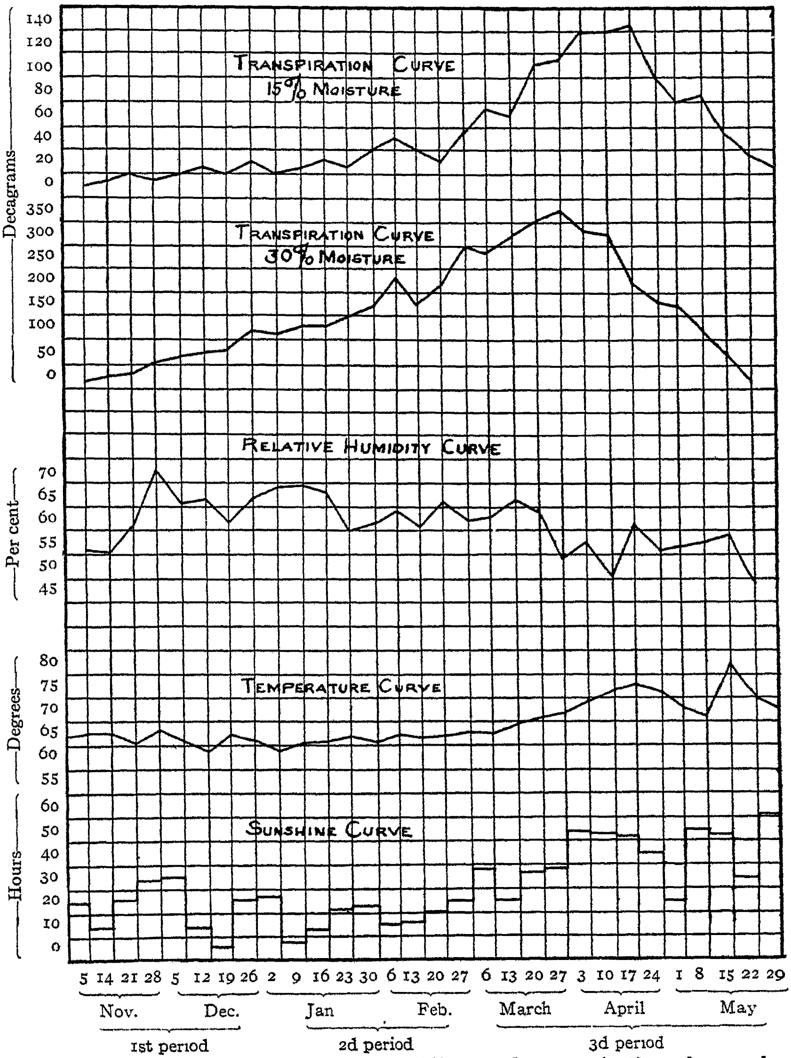

FIG. 108.—*Sunshine, temperature, humidity, and transpiration, by weeks, 1908–1909*

24.3 and 25.9. It is seen from these figures that the factors of temperature, humidity, and sunshine were practically the same during the two weeks. It is difficult, therefore, to account for this falling off in transpiration when we should expect an increase as the plants became larger.

In the two weeks ending on February 20 there was a very marked decrease in transpiration of all treatments as compared with the week ending on February 6. This was the case in all pots. In examining the curve it is found that during these two weeks of lower transpiration the temperature was slightly higher, the sunshine a little more, and the humidity about the same on an average as during the previous week. It was found, however, that most of the sunshine of these two weeks came on a relatively few days, the other days being almost without sunshine. During this time the greenhouse was covered with snow, which was probably responsible for the great lowering in transpiration as has already been suggested.

EFFECTS ON THE COMPOSITION OF WHEAT

Percentage and total weight of nitrogen

Nitrogen was determined in all plants harvested. The method used was the Gunning modification of the Kjeldahl method, as outlined in the methods of the Association of Official Agricultural Chemists. The results are summarized in the tables that follow.

TABLE 42. EFFECT OF DIFFERENT SOIL MOISTURE CONTENTS ON THE PERCENTAGE AND TOTAL WEIGHT OF NITROGEN IN WHEAT. NO FERTILIZER. 1909–1910

Soil moisture (percentage)	Number of pots	Percentage of nitrogen			Total weight of nitrogen per pot (in grams)		
		In grain	In straw	In grain and straw	In grain	In straw	In grain and straw
11	2	3.24	.69	1.38	.132	.077	.209
13	2	3.13	.49	1.28	.155	.064	.219
20	2	2.51	.42	1.04	.225	.088	.313
25	2	2.30	.34	.94	.236	.084	.320
37½	2	2.26	.40	.93	.309	.138	.447
45	2	2.39	.40	.90	.219	.106	.325

First, considering the composition of the grain, it is seen that the highest percentage of nitrogen was produced on the driest soil and that the percentage decreased as the moisture increased up to 37½ per cent; but that the grain on the excessively wet soil had a slightly higher percentage of nitrogen than that on the moderately wet soil. The percentage of nitrogen in the grain from the very dry soil was more than 35 per cent greater than that in the grain from the wet soil. The percentage of nitrogen in the straw ran in about the same way as that in the grain, except that the lowest was in the straw produced with 25 per cent moisture.

The straw with $37\frac{1}{2}$ per cent and that with 45 per cent moisture had the same percentage of nitrogen. The straw and the grain together, however, showed a lower nitrogen content where there was 45 per cent soil moisture, notwithstanding the fact that neither the straw nor the grain alone had a lower percentage. The explanation of this seeming paradox is found in the fact that there was proportionately more of the straw in one case than in the other, and its small amount of nitrogen reduced the general average.

It has been a common observation that a higher percentage of nitrogen is produced under drier conditions, but to have the nitrogen content rise when the soil moisture is raised above a certain limit is something entirely new to the author. The explanation that is usually given in the literature of the subject, for high nitrogen accompanying dry conditions, is that there is a hastened maturity and an arrested development. This theory would not be borne out by the data presented here, since, as was shown in Table 20, the period of growth was ten days longer in the plants producing the highest percentage of nitrogen in the grain than in those producing the lowest percentage. Also the length of the growing period, as well as the percentage of nitrogen, was greater in plants with 45 per cent water than in those with $37\frac{1}{2}$ per cent. As previously pointed out, the grain on the dry soil was plump and heavy, so that its high nitrogen could not be due to a shrinking of the kernels. The kernels raised with 45 per cent moisture were somewhat shrunken, however.

When the total weight of nitrogen produced in a pot is considered, the plants with $37\frac{1}{2}$ per cent moisture produced the most, notwithstanding the fact that their percentage was so low. This, of course, was due to the comparatively large crop.

TABLE 43. EFFECT OF HIGH AND OF LOW MOISTURE DURING DIFFERENT PERIODS OF GROWTH ON THE PERCENTAGE AND TOTAL WEIGHT OF NITROGEN IN WHEAT. AVERAGE FOR ALL FERTILIZER TREATMENTS. RESULTS FOR TWO YEARS

Percentage of soil moisture			Number of pots	Percentage of nitrogen							Total weight of nitrogen per pot (in grams)						
				In grain		In straw		In grain and straw		In roots	In grain		In straw		In grain and straw		In roots
First stage	Second stage	Third stage		1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909
30	30	30	6	2 62	2 05	40	.36	.85	82	99	261	390	152	.163	413	553	054
30	30	15	6	2.82	2 19	.48	.41	97	90	1 20	241	377	154	.181	.395	558	.081
30	15	15	6	2 98	2.31	.56	.44	1 02	98	1 36	196	.365	159	.169	.355	534	083
15	15	15	6	3.24	2.42	.60	.42	1.10	1.00	1.27	.128	.253	094	.113	.222	.366	.076
15	15	30	6	3.24	2.52	.66	.45	1.30	1.11	1.30	235	.354	.137	.135	.372	.489	.077
15	30	15	6	2.96	2.21	.49	.39	1.04	.93	1.24	.219	.334	.124	.147	.343	.481	.108

The crop produced with 30 per cent moisture during all three periods contained the lowest percentage of nitrogen in the total plant as well as in each part. The crop richest in nitrogen received 15 per cent moisture during the first two periods and 30 per cent during the third period. This was true of both grain and straw during both seasons. It will be noticed that the stage when the moisture was changed had a considerable influence. For example, in the plants receiving high moisture during but one period the percentage of nitrogen was much less where the high moisture was given during the first or the second period than where it was given during the third. The percentage of nitrogen in the roots varied similarly to that in the tops, but was different in some respects.

The total quantity of nitrogen produced per pot was also considerably affected by the changes in moisture, but the chief thing that affected it was the size of crop. Thus the treatment that gave the lowest percentages gave the largest total yield of nitrogen. Where the moisture was raised during but one period, the total nitrogen was decidedly greater than where the soil remained dry all the time.

TABLE 44. EFFECT OF FERTILIZERS ON THE PERCENTAGE AND TOTAL WEIGHT OF NITROGEN PRODUCED PER POT. AVERAGE FOR ALL MOISTURE TREATMENTS. RESULTS FOR TWO YEARS

Fertilizer	Number of pots	Percentage of nitrogen							Total weight of nitrogen per pot (in grams)						
		In grain		In straw		In grain and straw		In roots	In grain		In straw		In grain and straw		In roots
		1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909	1909–1910	1908–1909
None...	12	2.95	2.21	47	.37	1.05	.91	1.17	.166	.218	.096	.089	.262	.307	.070
Complete. ...	12	2.85	2.14	.50	.34	.97	.87	1.17	.227	.335	.135	.130	.362	.465	.077
High nitrogen.	12	3.13	2.47	.63	.52	1.14	1.11	1.33	.248	.452	.179	.236	.427	.688	.091

In practically every case the percentage of nitrogen was higher in the plants on the unfertilized soil than on that receiving the balanced complete fertilizer. On the soil with high nitrogen fertilizer, however, the nitrogen content of the crop was very much higher than with either of the other treatments.

When total weight of nitrogen produced per pot is considered, the unfertilized soil had the least. This was because of the considerably smaller crop.

Composition at different stages of growth

In 1908–1909 plants were harvested at the boot and bloom stages, as well as at maturity, and were analyzed, with the results given in Table 45:

TABLE 45. NITROGEN IN WHEAT AT VARIOUS STAGES OF GROWTH WITH DIFFERENT TREATMENTS. 1908–1909

Fertilizer	Soil moisture (percentage)	Percentage of nitrogen						Total weight of nitrogen in two pots (in grams)					
		In tops			In roots			Tops			Roots		
		Boot	Bloom	Maturity	Boot	Bloom	Maturity	Boot	Bloom	Maturity	Boot	Bloom	Maturity
None	30	1 23	.94	.83	1 36	1.23	.96	.434	.472	619	214	.132	.089
None	15	1 62	1.32	1.25	1.68	1.59	1.36	247	.245	.366	.168	.134	.130
Complete....	30	1 31	.88	.77	1 20	1.15	.98	.597	.668	.793	.273	.164	.115
Complete....	15	1 62	1.17	.96	1 50	1 35	1.30	.450	.465	.514	.312	.167	.171
High nitrogen	30	2 30	1.30	.95	1.98	1 26	1.03	.912	.986	1.068	.277	.159	.117
High nitrogen	15	1 85	1 52	1.20	1 62	1 58	1.16	.490	.497	455	292	.180	.152

The table brings out clearly the well-known fact that the percentage of nitrogen is higher during early than during late periods of growth. This is true for both the tops and the roots. The soils with low moisture always produced a higher percentage of nitrogen except in the case of the high nitrogen fertilizer at the boot stage, when there was a higher percentage of nitrogen accompanying the high moisture. This may have been due to the fact that the high nitrogen fertilizer did not become accessible to the plants with low moisture as early as it did to those with high moisture.

When the results for total nitrogen are examined, some very interesting relations are seen. In the roots the greatest total weight of nitrogen was present at the boot stage, and it had decreased decidedly by maturity. There was always a greater decrease in the wet soil than in dry.

Most of the nitrogen in the tops had been taken up by the boot stage, but there was usually a little increase up to maturity. With the high nitrogen fertilizer and low soil moisture, the greatest amount taken up was by the bloom stage and there was a decrease between that stage and maturity. It is a striking fact that on the drier soils a relatively larger amount of the nitrogen was taken up by the boot stage than on the wet soils.

Ash constituents

A determination was not made of the ash constituents of all treatments, and therefore no tables will be presented. The following determinations, however, were made in the wheat straw raised with high nitrogen fertilizer: crude ash, calcium, magnesium, potassium, and phosphoric acid. Since the work was not complete, no definite conclusions can be drawn, but sufficient work was done to bring out a few interesting points. The percentages of crude ash, calcium, magnesium, potassium, and phosphoric acid were all lower in straw grown with high moisture than in that grown

with low moisture. Where there was low moisture during one or two stages, the percentage of the ash constituents was also higher than where the high moisture was maintained throughout.

With all the constituents, and with phosphoric acid and potassium in particular, low moisture during the first period of growth increased the percentage of ash much more than low moisture during any other period.

SUMMARY

1. Experiments on the relation of soil moisture and fertilizers to soil conditions and to the growth of plants are of great interest to the investigator as well as to the tiller of the soil.

2. The important literature on this subject is reviewed topically.

3. Experiments were conducted in the greenhouse and in the laboratory, with wheat plants grown in pots containing soil with different moisture and fertilizer treatments. Studies were also made of certain properties of the cropped and the uncropped soils standing for long periods under the conditions named.

4. A study of the volume weight showed that the cropped soil was more compact than the uncropped, and the volume of the soil decreased as the moisture that it contained increased. Fertilized soils with crops were more compact than unfertilized soils.

5. In the cropped soil the particles were more flocculated than in the uncropped; and the flocculation was greater with a medium degree of soil moisture than with a very large or a very small degree, the least flocculation going with the very wet soil. Flocculation was increased by fertilizers, especially those that contained little sodium nitrate.

6. Nitrates were always higher in an uncropped than in a cropped soil, and were higher with 30 per cent moisture than in a drier or a wetter soil. Where the soil was kept saturated with moisture, practically no nitrates were present, denitrification having taken place. The nitrates were higher in soils to which nitrate fertilizers had been added.

7. The nitrite content of the soils was always low, but was higher on the uncropped soil than on the cropped and was higher where high nitrogen fertilizers had been added.

8. Unlike nitrates and nitrites, the ammonia was always higher in cropped than in uncropped soils. The amount of ammonia was never great and was not much affected by the soil moisture. It was highest where a high nitrogen fertilizer was used.

9. The total water-soluble salts were not taken up by plants as rapidly as were the nitrates, so that the ratio of soluble salts to nitrates was always higher in cropped than in uncropped soil. Fertilizers previously applied increased the total soluble salts.

10. No definite conclusions could be drawn regarding the number of bacteria in the soil. However, the number was usually greater with 15 per cent than with 30 per cent moisture. It was also slightly greater in unfertilized than in fertilized soil.

11. The easily soluble phosphoric acid was always higher in the uncropped than in the cropped soil, and higher in the fertilized than in the unfertilized soil. It varied with the soil moisture, but the variation was not regular.

12. The length of the various periods of growth was greatly affected by soil moisture and fertilizers. Wheat matured sixteen days earlier with 20 per cent moisture than with either 11 per cent or 45 per cent. The period at which high moisture was applied had an effect on the time of ripening. A well-balanced fertilizer caused an earlier maturity than one with high nitrogen or no fertilizer.

13. Tillering was promoted by high moisture and by fertilizers.

14. Plants were able to stand excessive moisture better when young than when older.

15. The attacks of mildew were severest on plants growing with high moisture and a high nitrogen fertilizer.

16. The number of nodes per culm was least with a medium, and most with the very high, soil moisture. The length of culms and of heads increased with the moisture up to $37\frac{1}{2}$ per cent, after which both decreased. The heads were proportionately longer in the dry than in the wet soil. The quantity of moisture during the early growth, more than at any other time, determined the head as well as the culm length. Fertilizers increased the number of nodes per culm, as well as the length of culm and of head.

17. The number of kernels of wheat per pot increased with the fertilizers. It also increased with the soil moisture up to $37\frac{1}{2}$ per cent, above which point it decreased. The number of kernels per head was greatest on the soil with a medium amount of moisture, but the weight of one hundred kernels was greatest on the very dry soil and least on the very wet. The kernels raised on the wet soils were soft and starchy in appearance.

18. Proportionately more of the dry matter in wheat had been produced by the boot stage in the dry soil than in the wet. After the boot stage the weight of roots, which could be washed out, decreased to maturity.

19. The greatest quantity of both grain and straw was produced with $37\frac{1}{2}$ per cent moisture, but the relative amount of grain was greatest with a medium low moisture (20 per cent). The period at which moisture was high or low greatly affected the ratio of straw to grain, there being proportionately more grain when the soil moisture was low during early

stages. Fertilizers increased the yield of both grain and straw, but especially of straw.

20. The total transpiration was greatly affected by fertilizers and soil moisture, and the greatest transpiration was in the plants producing the most dry matter. In relation to dry matter produced, water was transpired most economically with a medium degree of soil moisture, but the economy was greater on a very dry than on a very wet soil. Water was used most economically in the production of grain when the soil was kept comparatively dry up to the boot stage, and then kept wet until maturity. The total dry matter in the plant as a whole, however, was produced most economically when the soil was kept wet until the five-leaf stage, and drier from that stage to maturity. The manner in which fertilizers increased the economy of water transpired was dependent on the efficiency of the fertilizers and on the moisture conditions of the soil. The season and the variety of wheat affected the relation between transpiration and dry matter.

21. The relation between the amount of water transpired by the different treatments did not remain the same during all periods of growth. The manner in which transpiration responded to heat, sunshine, and humidity of the air depended, to an extent, on the soil treatment.

22. The percentage of nitrogen in both grain and straw was highest on the driest soil, and gradually decreased as the moisture increased up to $37\frac{1}{2}$ per cent; but as the soil approached saturation the percentage of nitrogen in the grain slightly increased. The grain with the highest percentage of nitrogen was plump and had a flinty appearance. The highest percentage of nitrogen did not go with the earliest maturity.

23. The period of growth at which high or low moisture was given greatly affected the composition of wheat. The condition that gave the highest percentage of nitrogen both in the grain and straw was where the moisture was low up to the boot stage, and high from that stage to maturity. It will be remembered that this was also the treatment that used water most economically in producing grain. The lowest nitrogen was found where the moisture was high during all periods.

24. The high nitrogen fertilizer always increased the nitrogen content of the crop. While the percentage of nitrogen was not so great in the crop produced with complete fertilizer as with no fertilizer, yet the total weight of nitrogen was much greater, due to the larger crop.

25. The percentage of nitrogen in the crop rapidly decreased from the boot stage to maturity, the decrease being greater in the tops than in the roots, and greater in the crops on the wet soil than in those on the dry. The total weight of nitrogen in the roots was greatest at the boot stage and decreased to maturity. In the tops, however, there was usually

a slight increase in total nitrogen after the boot stage. In the dry soil a greater proportion of the total nitrogen had been taken up by the boot stage than had been taken up in the wet soil.

26. The percentage of crude ash, calcium, magnesium, potassium, and phosphoric acid was lower in wheat straw grown with high moisture than in that grown with low moisture.

27. These experiments bring out clearly the facts that the moisture relations of plants are greatly affected by the fertility of the soil, and that the effect of a fertilizer is dependent on the amount of soil moisture. They emphasize also the fact that fertilizer experiments, in order to be of value, must be made under widely varying moisture conditions; and that experiments with the use of moisture by plants, in order to be conclusive, must include a number of fertility conditions.

BIBLIOGRAPHY[4]

Abbe, Cleveland

1905 Relation of water to crops. Rainfall and sugar beets. *In* A first report on the relations between climates and crops. U. S. Weather Bureau. Bul. 36:116–127.

Bouyoucos, George J.

1912 Transpiration of wheat seedlings as affected by soils, by solutions of different densities, and by various chemical compounds. Amer. Soc. Agron. Proc. **3** (1911): 130–191.

Briggs, L. J., and Shantz, H. L.

1913 a The water requirement of plants. I.—Investigations in the Great Plains in 1910 and 1911. U. S. Plant Indus. Bur. Bul. 284: 1–49.

1913 b Same. II.—A review of the literature. U. S. Plant Indus. Bur. Bul. 285: 1–96.

Buckman, H. O.

1911 Moisture and nitrate relations in dry-land agriculture. Amer. Soc. Agron. Proc. **2** (1910): 121–138.

Bünger, J.

1908 Neues über den einfluss der ernährung des wassers, und der beleuchtung auf entwicklung und organization der höheren gewächse. Naturw. wochenschr. **23**:43:674–686.

Daszewski, A. von, and Tollens, B.

1900 Der einfluss des wassers und der düngung auf die zusammensetzung der asche der kartoffelpflanze. Journ. landw. **48**: 223–249.

Davidson, R. J.

1895 Analyses of parts of tobacco plant at different stages of growth. Virginia Agr. Exp. Sta. Bul. 50: 33–52.

Davis, R. O. E.

1911 The effect of soluble salts on the physical properties of soils. U. S. Soils Bur. Bul. 82: 1–38.

Davis, R. O. E., and Bryan, H.

1910 The electrical bridge for the determination of soluble salts in soils. U. S. Soils Bur. Bul. 61: 1–36.

[4] The bibliography contains only the articles reviewed in the text of the bulletin It is not offered as a complete bibliography of the subject.

Déléano, N. T.

1907 Étude sur le rôle et la fonction des sels minéraux dans la vie de la plante. Reviewed in Bot. centbl. **107** (1908):4. *From* Inst. Bot. Univ. Genève, sér. 7, fasc. 9, 48 p.

Eberhardt, Ph.

1903 Influence de l'air sec et de l'air humide sur la forme et sur la structure des végétaux. Ann. sci. nat. Botanique. Sér. 8:**18**:61–153.

Ellett, W. B., and Hill, H. H.

1913 A study of the effect of fertilizers on the soluble plant food in the soil and on the crop yield. Virginia Agr. Exp. Sta. Ann. rept. **1911–1912**:116–133.

Fest, Franz

1908 Über den zeitlichen verlauf der nährstoffaufnahme und trockensubstanzproduktion bei der buschbohne unter verschiedenen düngungs- und witterungsverhältnissen. Journ. landw. **56**: 1–47.

Fleischer, M.

1897 The influence of the nitrogen content of the soil upon the ratio between grain and straw. Cited in Exp sta. rec. **8**:781–782. *From* Deut. landw. presse **24**: 17:145.

Fortier, S.

1903 Soil moisture in relation to crop yield. Montana Agr. Exp. Sta. Rept. **9** (1902):101–116.

Free, E. E.

1910 The phenomena of flocculation and deflocculation. Journ. Franklin Inst. **169**:421–438; concluded **170**:46–57.

Frei, August

1910 Untersuchungen über die bestandteile der haferkörner unter dem einfluss verschiedener witterungs- und anbauverhältnisse. Landw. vers. stat. **72**:161–310.

Gain, Edmond

1895 a Action de l'eau du sol sur la végétation. Rev. gén. bot. **7**:15–26, 71–84, 123–138. Also cited in Exp. sta. rec. **6**:869–870.

1895 b Recherches sur le rôle physiologique de l'eau dans la végétation. Ann. sci. nat. Botanique. Sér. 7:**20**:63–215. Also cited in Exp. sta. rec. **7**:366–370.

Gamble, W. P.
1906 The effect of different soils upon the composition of crops. Ontario Agr. Col. and Exp. Farm. Ann. rept. **31** (1905): 93–100.

Gardner, F. D.
1908 Fertility of soils as affected by manures. U. S. Soils Bur. Bul. 48:1–59.

Hall, A. D.
1905 The analysis of the soil by means of the plant. Journ. agr. sci. **1**:65–88.

Harris, F. S.
1911 Long versus short periods of transpiration in plants used as indicators of soil fertility. Amer. Soc. Agron. Proc. **2** (1910):93–102.

Hébert, A.
1892 Contribution à l'étude du développement des céréales. Annales agron. **18**:33–47.

Heinrich, R.
1904 Ueber die wasser mengen welche die haferpflanze aus verschiedenes nährstoff-concentrationen während ihrer vegetationszeit verbraucht.
Landw. Vers. Stat. Rostock. Ber. **2**:170–174.

Hunt, T. F.
1904 The cereals in America, p. 69.

Jensen, C. A.
1910 Seasonal nitrification as influenced by crops and tillage. U. S. Plant Indus. Bur. Bul. 173:1–31.

Khankhoje, Pandurang
1914 Some factors which influence the water requirements of plants. Amer. Soc. Agron. Journ. **6**:1–23.

Kiesselbach, T. A.
1910 Transpiration experiments with the corn plant. Nebraska Agr. Exp. Sta. Ann. rept. **23**:125–139.

King, F. H.
1892 Investigations relating to soil moisture. Wis. Agr. Exp. Sta. Ann. rept. **8** (1890–1891): 100–134.
1893 a The amount of water required to produce a pound of dry

King, F. H. (*continued*)
matter in barley, oats, corn, clover, and peas in Wisconsin. Wis. Agr. Exp. Sta. Ann. rept. **9** (1891–1892):94–100.
1893 b Influence of deep and shallow cultivation on the water content of the soil. Wis. Agr. Exp. Sta. Ann. rept. **9** (1891–1892): 101–105.
1893 c Influence of farm yard manure on the movement and amount of water in soil. Wis. Agr. Exp. Sta. Ann. rept. **9** (1891–1892): 106–111.
1893 d Natural distribution of roots in field soils. Wis. Agr. Exp. Sta. Ann. rept. **9** (1891–1892): 112–120.
1894 a The amount of water required to produce a pound of dry matter in Wisconsin. Wis. Agr. Exp. Sta. Ann. rept. **10** (1892–1893): 152–159.
1894 b The natural distribution of roots in field soils. Wis. Agr. Exp. Sta. Ann. rept. **10** (1892–1893): 160–164.
1907 A text-book of the physics of agriculture, p. 1–604.

Kolkunov, V.
1905 The production of races of cultivated plants inured to drought. Cited in Exp. sta. rec. **19**:225. *From* Izv. Kiev Politek. Inst., p. 82.

Lawes, J. B.
1850 Experimental investigation into the amount of water given off by the plants during their growth; especially in relation to the fixation and source of their various constituents. Hort. Soc. London. Journ. **5**:38–63.

Leather, J. W.
1910–1911 Water requirements of crops in India. Memoirs Dept. Agr. India. Chem. ser. **1**: 133–184, 205–281.

Le Clerc, J. A.
1907 The effect of climatic conditions on the composition of durum wheat. U. S. Agr. Dept. Yearbook **1906**: 199–212.

Le Clerc, J. A., and Breazeale, J. F.
1909 Plant food removed from growing plants by rain or dew. U. S. Agr. Dept. Yearbook **1908**: 389–402.

Livingston, B. E.
1905 Relation of transpiration to growth in wheat. Bot. gaz. **40**: 178–195.
1906 The relation of desert plants to soil moisture and to evaporation. Carnegie Institution of Washington. Pub. no. 50: 1–78.

Lyon, T. L.

1905 Improving the quality of wheat. U. S. Plant Indus. Bur. Bul. 78:1–120.

1907 Modifications in cereal crops induced by changes in their environment. Soc. Prom. Agr. Sci. Proc. **28**:144–163.

1910 The relation of wheat to climate and soil. Amer. Soc. Agron. Proc. **1** (1907):108–125.

Lyon, T. L., and Bizzell, J. A.

1913 a The plant as an indicator of the relative density of soil solutions. Amer. Soc. Agron. Proc. **4** (1912):35–49.

1913 b Some relations of certain higher plants to the formation of nitrates in soils. Cornell Univ. Agr. Exp. Sta. Memoir no. 1:1–111.

Maercker, Max

1896 Versuche über die beeinflussung des wasserverbrauchs der pflanzen durch die kalirohsalze. Agr. Chem. Vers. Stat. Halle. Jahrb. **1895**:15–16.

Mayer, Adolf

1898 Über den einfluss kleinerer oder grösserer mengen von wasser auf die entwickelung einiger kulturpflanzen. Journ. landw. **46**:167–184.

Meyer, Karl

1909 Über den einfluss verschieden hohen wassergehalts des bodens in den einzelnen vegetationsstadien bei verschiedener N-düngung auf die entwicklung des Göttinger begrannten square-head-winterweizens. Journ. landw. **57**:351–384.

Montgomery, E. G., and Kiesselbach, T. A.

1912 Studies in water requirements of corn. Nebraska Agr. Exp. Sta. Bul. 128:1–15.

Morgan, J. O.

1912 The effect of soil moisture and temperature on the availability of plant nutrients in the soil. Amer. Soc. Agron. Proc. **3** (1911):191–249.

Ohlmer, W.

1908 Über den einfluss der düngung und der bodenfeuchtigkeit bei gleichem standraum auf die anlage und ausbildung der ähre und die ausbildung der kolbenform beim Göttinger begrannten squarehead-winterweizen. Journ. landw. **56**: 153–171.

Pagnoul, A.

1898 Experiments on the transpiration of plants. Cited in Exp. sta. rec. **11**:118. *From* Bul. Sta. Agron. Pas de Calais, p. 10–15.

Pfeiffer, Th., Blanck, E., and Friske, K.

1913 Der einfluss verschiedener vegetationsfaktoren. namentlich des wassers, auf die erzielung von maximalerträgen in vegetationsgefässen. Landw. vers. stat. **82**:237–298.

Polle, R.

1910 Über den einfluss verschieden hohen wassergehalts, verschiedener düngung und festigkeit des bodens auf die wurzelentwicklung des weizens und der gerste im ersten vegetationsstadium. Journ. landw. **58**:297–344.

Preul, Franz

1908 Untersuchungen uber den einfluss verschieden hohen wassergehaltes des bodens in den einzelnen vegetationsstadien bei verschiedenem bodenreichtum auf die entwickelung der sommerweizenpflanze. Journ. landw. **56**:229–271.

Prianishnikov, D.

1900 The influence of the moisture of the soil on the growth of plants. Cited in Exp. sta. rec. **13**:631. *From* Zhur. opuitn. agron. **1**:1:3–20.

Pulman, I. A.

1904 Influence of the humidity of the soil at various periods of development of buckwheat on the yield of grain. Cited in Exp. sta. rec. **16**:348. *From* Zhur. opuitn. agron. **5**:1:68–72.

Reed, H. S.

1910 The effect of certain chemical agents upon the transpiration and growth of wheat seedlings. Bot. gaz. **49**:81–109.

Schindler, Franz

1893 Der weizen in seinen beziehungen zum klima und das gesetz der korrelation, p. 1–175.

Schreiner, Oswald, and Failyer, G. H.

1906 Colorimetric, turbidity, and titration methods used in soil investigations. U. S. Soils Bur. Bul. 31:1–60.

Schroeder, R. R.

1896 Development and transpiration of barley under the influence of different degrees of humidity and nutrition in the culture media. Cited in Exp. sta. rec. **8**:954–955. *From* Ann. Inst. Agron. Moscou **2**:2:188–226.

Schulze, B.
1904 Studien über die entwickelung der roggen- und weizenpflanze. Landw. jahrb. **33**:405–441.

Seelhorst, C. von
1899 Über den wasserverbrauch der haferpflanze bei verschiedenem wassergehalt und bei verschiedener düngung des bodens. Journ. landw. **47**:369–378.
1900 Neuer beitrag zur frage des einflusses des wassergehalts des bodens auf die entwicklung der pflanzen. Journ. landw. **48**:165–177.
1906 Über den wasserverbrauch von roggen, gerste, weizen, und kartoffeln. Journ. landw. **54**:316–342.
1911 Die bedeutung des wassers im leben der kulturpflanzen. Journ landw. **59**:259–291.

Seelhorst, C. von, and Bünger, J.
1907 Versuche mit sommerweizen. Journ. landw. **55**:246–260.

Seelhorst, C. von, and Fresenius, L.
1905 Der einfluss der bodenfeuchtigkeit auf den gehalt des haferstrohs an gesamt- und an eiweiss-N. Journ. landw. **53**: 27–28.

Seelhorst, C. von, and Georgs, N.
1900 Der einfluss der düngung und des wassergehaltes des bodens auf den bau und auf die zusammensetzung der gerstenpflanze resp. des gerstenkornes. Journ. landw. **48**:325–347.

Seelhorst, C. von, Georgs, N., and Fahrenholtz, F.
1900 Einfluss des wassergehaltes und der düngung des bodens auf die produktion und die zusammensetzung von futterpflanzen, italienisches raigras, und klee. Journ. landw. **48**:265–286.

Seelhorst, C. von, and Krzymowski, ——
1905 Versuch über den einfluss, welchen das wasser in den verschiedenen vegetationsstadien des hafers auf sein wachstum ausübt. Journ. landw. **53**:357–370.
1909 Das reifen verschiedener sommerweizen-varietäten bei verschiedener bodenfeuchtigkeit. Journ. landw. **57**:113–114.

Seidler, L., and Stutzer, A.
1908 Untersuchungen über die durch hafer in den einzelnen vegetationsperioden bewirkte aufnahme und abgabe von nährstoffen. Journ. landw. **56**:273–278.

Shutt, F. T.
1909 The influence of environment on the composition of wheat. Journ. Soc. Chem. Indus. **28**:336.

Stewart, Robert, and Greaves, J. E.
1909 A study of the production and movement of nitric nitrogen in an irrigated soil. Utah Agr. Exp. Sta. Bul. 106:65–96.

Thatcher, R. W.
1912 The relation of protein content of wheat to rainfall. Amer. Soc. Agron. Proc. 3(1911):42–45.
1913 A report of the investigations concerning the chemical composition of wheat. Washington Agr. Exp. Sta. Bul. **111**: 1–79.

Tinsley, J. D., and Vernon, J. J.
1904 Soil moisture investigations for the season of 1903. New Mexico Agr. Exp. Sta. Bul 48:1–15.

Traphagen, F. W.
1903 Hardening of soft wheat. Softening of hard wheat. Montana Agr. Exp. Sta. Rept. **9**(1902):59–60.

Wagner, Max
1908 Versuche über den einfluss verschiedener ernährungsverhältnisse auf den verlauf der nährstoffaufnahme und den morphologischen bau der pflanze. Landw. vers. stat. **69**: 161–233.

Warington, Robert
1900 Lectures on some of the physical properties of soil, p. 1–231.

Waters, H. J., and Hess, E. H.
1896 . Effect of fertilizers on the proportion of grain to straw and stover. Pennsylvania State College. Rept. **1895**:2:220–223.

Whitson, A. R., and Stoddart, C. W.
1904 Studies on the influence of the soil on the protein composition of crops. Wisconsin Agr. Exp. Sta. Ann. rept. **21**:193–199.

Widtsoe, J. A.
1902 Irrigation investigations in 1901. Utah Agr. Exp. Sta. Bul. 80:69–199.
1903 The influence of soil moisture upon the chemical composition of certain plant parts. Amer. Chem. Soc. Journ. **25**: 1234–1243.

Widtsoe, J. A. (*continued*)

1909 Factors influencing evaporation and transpiration. Utah Agr. Exp. Sta. Bul. 105:1–64.

1912 The production of dry matter with different quantities of irrigation water. Utah Agr. Exp. Sta. Bul. 116:1–64.

Widtsoe, J. A., and McLaughlin, W. W.

1912 The movement of water in irrigated soils. Utah Agr. Exp. Sta. Bul. 115:195–268.

Widtsoe, J. A., and Merrill, L. A.

1912 a The yields of crops with different quantities of irrigation water. Utah Agr. Exp. Sta. Bul. 117:65–119.

1912 b Methods for increasing the crop producing power of irrigation water. Utah Agr. Exp. Sta. Bul. 118:121–164.

Widtsoe, J. A., and Stewart, Robert

1912 a The effect of irrigation on the growth and composition of plants at different periods of development. Utah Agr. Exp. Sta. Bul. 119.165–200.

1912 b The chemical composition of crops as affected by different quantities of irrigation water. Utah Agr. Exp. Sta. Bul. 120:201–240.

Wilfarth, H., Römer, H., and Wimmer, G.

1906 Über die nährstoffaufnahme der pflanzen in verschiedenen zeiten ihres wachstums. Landw. vers. stat. **63**:1–70.

Williams, C. B.

1895 Estimation of phosphoric acid in soils by double precipitation with molybdic solution and titration of the ammonium phosphomolybdate with standard alkali Amer. Chem. Soc. Journ. **17**:925–926.

Wilms, J., and Seelhorst, C. von

1898 Beitrag zur lösung der frage, ob der wassergehalt des bodens die zusammensetzung der pflanzentrockensubstanz an N und aschen beeinflusst. Journ. landw. **46**:413–426.

Yanovchik, F.

1900 On the evaporation of water by plants. Cited in Exp. sta. rec. **13**:225. *From* Selsk. Khoz. i Lyesov. **197**:487–508.

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CORNELL UNIVERSITY
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OF THE COLLEGE OF AGRICULTURE

VARIATION AND CORRELATION OF OATS (AVENA SATIVA)

PART I. STUDIES SHOWING THE EFFECT OF SEASONAL CHANGES ON BIOMETRICAL CONSTANTS

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PART I. STUDIES SHOWING THE EFFECT OF SEASONAL CHANGES ON BIOMETRICAL CONSTANTS[1]

(*Received for publication April 9, 1914*)

H. H. LOVE AND C. E. LEIGHTY[2]

Although considerable effort has been directed toward the breeding of oats, yet little is known concerning the variation and correlation of characters of this crop. Little evidence has been given to show what characters, if any, may be used as a basis for selection, or whether all characters are so variable and so affected by different seasons as to render impossible their use as a means of improvement. The same is true in regard to the correlation of characters. How are they affected by varying conditions from year to year, and is their relationship stable enough to be of importance in selection and improvement? From the study of the methods of oat-breeding, certain questions regarding the variation and correlation of the various characters naturally arise. Some of these are:

1. Do the tallest plants produce the most grain?
2. Do the tallest plants produce the largest seed?
3. As the number of culms increases, does the average yield per culm increase?
4. As the number of culms increases, does the average number of kernels produced by each culm increase or decrease?
5. As the number of culms increases, does the average weight of kernel increase or decrease?
6. Are these various relationships stable from year to year?

In an attempt to answer these questions it is the purpose of this paper to present evidence on the variation and correlation of the various characters of oats when the crops have been grown in different seasons, thereby coming under the influence of diverse environmental conditions.

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[2] In cooperation with the Bureau of Plant Industry, United States Department of Agriculture.

MATERIAL AND METHODS

Owing to the fact that the commercial varieties of grains are composed of a mixture of several types, and that as they are grown from year to year there may be a tendency toward a selective elimination of certain types, it was thought advisable to make this first study on a pure line. For this reason a pure line of Sixty Day oats was grown for the purpose.

The first year (1908) this pure line was grown in a drill row. It was consequently impossible to harvest the crop plant by plant. The entire row was harvested, and the studies were made on the individual culms.

In the years 1909, 1910, 1911, and 1912 the planting was done in a different manner. The soil was prepared and marked off in rows one foot apart, then the seeds were dropped about two inches apart in the rows. By this method it was possible to harvest the plants as individuals, so that the notes could be taken on each plant. The crops were all grown on the same type of soil with the exception of that of 1910, when it was necessary to use a different soil type. This was unfortunate, but unavoidable.

The crop of 1911 was so injured by storms that it was impossible to gather any statistical data for it.

The climatic conditions of 1910 were not so favorable as those of the other years. The month of June was very dry, followed by a dry July with high temperature. The table on the following page gives the amount of rainfall, hours of sunshine, and temperature for the seasons considered. From this table it is apparent that the average rainfall for the months of March, April, May, June, and July was much lower in 1910 than in any other of the years considered. This is important, as will be shown later by the behavior of the correlation constants.

At the time of harvesting, the individual plants were bound, and were thus preserved with all their culms intact. After being pulled they were well dried, and thereafter were handled carefully so that there would be as little shattering as possible.

The data for the years 1909, 1910, and 1912 used in this publication are: (1) Average height of plant, in centimeters, obtained by measuring separately each culm of a plant from the base of the culm to the base of the apical spikelet, and dividing the sum of these measurements by the number of culms making up the plant. (2) Total yield of plant,

TABLE 1. CLIMATIC CONDITIONS

	January	February	March	April	May	June	July
			Rainfall				
1908	2 27	2 47	2.24	3.85	4.30	1.26	4.75
1909	2.64	2 80	1.78	3.18	2 15	3.97	1 62
1910	3 07	3.31	0.30	3.66	4.20	1.14	1.62
1912	1 63	1 28	2 73	2.97	3.58	1.37	2.64
			Hours of sunshine				
1908	....	127	133	152	163	346	282
1909	86	84	165	197	231	298	337
1910	163	133	244	216	231	259	303
1912	129	178	182	172	280	359	337
			Temperature				
1908	25.2	20.8	35.0	44.2	58.8	67.6	72.7
1909	28 0	30 8	31.6	43.3	55.7	66 4	68.6
1910	25.3	23 2	42.0	49 8	54 2	63 8	71.4
1912	16.6	21 4	28 8	44 5	58 0	63.2	70.9

in grams, obtained by weighing the kernels produced. (3) Average yield of culm per plant, in grams, obtained by dividing the total yield by the number of culms of the plant. (4) Total number of kernels per plant. (5) Average number of kernels per culm per plant, obtained by dividing the total number of kernels by the number of culms of the plant. (6) Average weight of kernels per plant, in milligrams, obtained by dividing the total weight in grams of the kernels produced by their total number and expressing the result in milligrams. (7) Average number of spikelets per culm per plant, obtained by dividing the total number of spikelets by the number of culms of the plant. (8) Average number of kernels per spikelet per plant, obtained by dividing the total number of kernels produced by the plant by the total number of spikelets. (9) Number of culms per plant.

The data for 1908 are the actual determinations for single culms, as no averages for plants were possible because of the method used in taking the data. Items 2, 4, 8, and 9 in the preceding paragraph are not dealt with for that year, and the expression of the other items must be modified to suit the requirements.

After the data had all been taken, the values for the characters used in this study were placed on cards. The data for each individual were placed on a separate card, each card thus representing an individual. The cards were then sorted for the various frequency distributions and correlation tables. This method saves much time, since it is thus made possible to group the cards according to one character — such as average height of plant — and then, by keeping the different groups separate, to distribute them into correlation tables much more easily than two characters can be distributed into correlation tables from data not thus arranged.

For the first year, 1908, there were 825 individual culms used. For the years 1909, 1910, and 1912, plants were made the unit, as stated above, and there were 500, 400, and 400 used for the three years, respectively. The ordinary method for determining the mean, standard deviation, coefficient of correlation, and coefficient of variability was used. All determinations were made to the fourth decimal place and were recorded to the third. The mathematical work was doubly checked, and the authors feel that the constants are correct.

REVIEW OF LITERATURE

In recent years a number of biometrical studies have been made on the small grains by various investigators.

Waldron (1910)[3] reports biometrical results for oats and wheat, but the results for oats are discussed at length elsewhere in this paper and need not be considered here.

Love (1912), in a study of the question of large and small grain, reports biometrical results for a pure line of wheat. These results (Table 2) show that yield is associated with tall plants and with plants that produce a large number of kernels. At the same time the heaviest seed is produced in general on the tallest plants, on plants producing the largest number of seeds, and on the heaviest-yielding plants.

Myers (1912) made biometrical studies of a variety of wheat grown on plots of different fertility. He found correlations between: (1) number of culms and average weight of kernel, of $.013 \pm .032$ on ordinary soil and $.301 \pm .027$ on sand; (2) height and average weight of kernel, of $.480 \pm .025$ on ordinary soil and $.509 \pm .022$ on sand; (3) gross weight of

[3] Dates in parenthesis refer to "Literature cited," page 936.

TABLE 2. CORRELATION COEFFICIENTS FOR THE DIFFERENT CHARACTERS OF WHEAT STUDIED

Characters	Correlation coefficients
Height of plant and yield	0.294 ± 0.032
Number of kernels per plant and yield	0.985 ± 0.001
Height of plant and average weight of grains	0.278 ± 0.033
Total number of grains per plant and average weight of grains	0.251 ± 0.033
Yield in grams and average weight of grains in milligrams	0.327 ± 0.031

culm and yield, of .925±.004 on ordinary soil and .890±.006 on manured soil. All correlations were greater on the poorer soil. Increased fertility tended to decrease variability.

Roberts (1912) made biometrical studies of three pure strains of wheat for two years. The characters considered were culm length, head length, number of culms per plant, number of grains per head, and yield. The means of the different characters are considerably modified by conditions of growth, increasing with improvement in these conditions, but a better growing season reduces their variability. A high positive correlation was found between yield and number of culms, and culm length and number of grains, and a fairly high positive correlation between culm length and head length, also between number of culms per plant and both culm length and number of grains. The correlation between culm length and head length varied considerably from one year to another, but there was little variation observed in the correlation between culm length and number of kernels.

The results reported by Leighty (1912) on a pure line of oats are incorporated in this paper and need not be discussed here.

Whitcomb (1913) reports biometrical results on two varieties of barley. The coefficients of correlation for average of plant, of the two varieties, are given in the table on the following page.

DEVELOPMENT AND VARIATION

The means, standard deviations, and coefficients of variability for the different characters under observation are given in Table 3. The mean

	New Zealand	Berkeley
Yield per culm and height of culm.........	511±.029	.654±.022
Yield per culm and number of kernels per culm........	836±.012	.864±.010
Yield per culm and number of spikelets per culm..........	.965±.020	.521±.028
Yield per culm and average weight per kernel	.790±.015	.753±.017
Average weight per kernel and height of culm	.221±.037	.384±.033
Average weight per kernel and number of kernels per culm	.365±.034	.378±.033

for average height of plant in centimeters is 52.990±.181 for 1908. The plants were grown in drill rows, and the conditions were not so favorable for the development of tall culms in that year as they were in later years. The means for average height in the other years are, in order of value, 70.840±.234 for 1910, 75.200±.182 for 1912, and 76.110±.277 for 1909. The differences in height are not great for these years. The variability for this character as indicated by the standard deviation[4] is greatest for 1909 (the year for which the mean is largest), being then 9.188±.196; but the variability for 1908, 7.715±.128, is next in order although the mean is smallest for that year. This doubtless results from the fact that culms were then the units. For 1912 the variability is least, being then 5.405±.129; for 1910 it is 6.950±.166.

The means for the total yield of plant vary from 3.458±.045 grams for 1910 to 4.032±.068 for 1909 and 7.962±.113 for 1912. The variation as indicated by the standard deviations is in the same order, being 1.323±.032 for 1910, 2.249±.048 for 1909, and 3.353±.080 for 1912. The average yield of culm per plant has a mean for 1908 of .409±.006 gram, this being lower than the mean for any other year. For 1910 the mean is .962±.008, for 1909 it is .978±.010, and for 1912 it is 1.266±.008. The standard deviations for the average yield are

[4] Variability is expressed by means of both the standard deviation and the coefficient of variability. The standard deviation expresses the variation as measured from the mean, and is expressed in the units of measurement. It is thus an absolute expression of variability. The coefficient of variability is a relative expression by means of which, for instance, a variable character whose data have been recorded in pounds is directly comparable with another whose data have been measured in inches. For the points under consideration the standard deviation very well expresses conditions as they actually are; at the same time the coefficient of variability is used also in these discussions.

TABLE 3. MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIABILITY FOR THE DIFFERENT CHARACTERS UNDER OBSERVATION

	1908	1909	1910	1912
	M	M	M	M
Average height of plant in centimeters	52.990 ± .181	76 110 ± 277	70 840 ± .234	75.200 ± 182
Total yield of plant in grams		4.032 ± .068	3.458 ± .045	7.962 ± .113
Average yield of culm per plant in grams	.409 ± .006	.978 ± .010	962 ± .008	1 266 ± .008
Total number of kernels per plant		247.500 ± 4.124	202.150 ± 2 657	548.650 ± 7 589
Average number of kernels per culm per plant	23.580 ± 327	59 800 ± .559	56.020 ± .484	86 600 ± 514
Average weight of kernels per plant in milligrams	16.114 ± 062	16 172 ± 040	17.100 ± 059	14 485 ± 036
Average number of spikelets per culm per plant	15.320 ± 173	32.340 ± .247	35 400 ± 245	
Average number of kernels per spikelet per plant		1 803 ± 007	1 506 ± .006	
Number of culms per plant		3.948 ± 043	3.568 ± 031	6 150 ± 066
	σ	σ	σ	σ
Average height of plant in centimeters	7.715 ± .128	9.188 ± 196	6 950 ± .166	5.405 ± .129
Total yield of plant in grams		2.249 ± .048	1 323 ± .032	3.353 ± 080
Average yield of culm per plant in grams	.257 ± 004	315 ± .007	.241 ± 006	.239 ± .006
Total number of kernels per plant		136.560 ± 2 909	78.800 ± 1.879	225 050 ± 5.367
Average number of kernels per culm per plant	13.910 ± .231	18 508 ± .394	14.340 ± .342	15.250 ± .364
Average weight of kernels per plant in milligrams	2.626 ± .044	1 311 ± 028	1.741 ± .042	1 056 ± 025
Average number of spikelets per culm per plant	7.375 ± 122	8.171 ± .174	7 270 ± .173	
Average number of kernels per spikelet per plant		.229 ± .005	.172 ± .004	
Number of culms per plant		1.415 ± .030	.931 ± .022	1.972 ± .047
	C	C	C	C
Average height of plant in centimeters	14.559 ± .252	12 072 ± .261	9.811 ± .234	7.187 ± .171
Total yield of plant in grams		55.779 ± 1.514	38.259 ± 1.037	42.113 ± 1.169
Average yield of culm per plant in grams	62.836 ± 1 396	32.209 ± .754	25.052 ± .634	18.878 ± 466
Total number of kernels per plant		55.176 ± 1.490	38 981 ± 1.062	41.019 ± 1.131
Average number of kernels per culm per plant	58.991 ± 1 276	30 950 ± .720	25.598 ± .650	17.610 ± .433
Average weight of kernels per plant in milligrams	16.296 ± 278	8 106 ± .173	10.181 ± 245	7.290 ± .174
Average number of spikelets per culm per plant	48.140 ± .968	25.266 ± .572	20.537 ± .510	
Average number of kernels per spikelet per plant		12.701 ± .275	11.388 ± .275	
Number of culms per plant		35.841 ± .856	26.093 ± 663	32.065 ± .840

.239±.006 for 1912, .241±.006 for 1910, .257±.004 for 1908, and .315±.007 for 1909. The least variation exists where the mean is largest, but the decrease is not in proportion to the decrease in the mean.

In number of kernels the same conditions are found as obtained in yield. The means for total number of kernels are, in order of value, 202.150± 2.657 for 1910, 247.500± 4.124 for 1909, and 548.650±7.589 for 1912. The means for average number per culm are, in order, 23.580±.327 (total number per culm) for 1908, 56.020±.484 for 1910, 59.800±.559 for 1909, and 86.600±.514 for 1912. In variability the order differs, being for total kernels 78.800±1.879 for 1910, 136.560±2.909 for 1909, and 225.050±5.367 for 1912; and for average number 13.910±.231 for 1908, 14.340±.342 for 1910, 15.250±.364 for 1912, and 18.508±.394 for 1909. The variability does not differ materially, but it is not greatest where the average yield is greatest.

The mean and the variability of average weight of kernels (milligrams in each case) are least for 1912, the mean being 14.485±.036 and the standard deviation 1.056±.025. The mean is greatest for 1910, being 17.100±.059, while the standard deviation for that year is 1.741±.042. The means for the other two years are about the same, being slightly above 16.1 in each case; the variation, however, is much greater for 1908, being then 2.626±.044, while for 1909 it is 1.311±.028.

The mean for number of spikelets per culm per plant is 15.320±.173 for 1908. This constant is again much smaller than the one for 1909, which is 32.340±.247, while the one for 1910 is 35.400±.245, the reason being undoubtedly the same as is given for the differences noted above. The variability is greatest for 1909, when the standard deviation is 8.171±.174. There is little difference in this respect between the other two years, the figures being 7.375±.122 for 1908 and 7.270±.173 for 1910.

The means for average number of kernels per spikelet were determined for only two years. For 1910 the mean is 1.506±.006, for 1909 it is 1.803±.007; while the standard deviations are .172±.004 and .229±.005, respectively. There is not much variability in this character, as is indicated by this constant.

The mean number of culms produced by the plant varies from 3.568± .031 for 1910 to 3.948±.043 for 1909, and 6.150±.066 for 1912, when it is greatest. The variability increases as does the mean, being

.931 ± .022 for 1910, 1.415 ± .030 for 1909, and 1.972 ± .047 for 1912. The number of culms produced by a plant is very responsive to environmental conditions. Under the best conditions here dealt with the number of culms has been largely increased, and the variability has also increased with the better conditions for growth.

The means for 1910 are less than those for 1909 and 1912 in average height, number of culms, total number and average number of kernels, total and average yield. When spikelet characters in 1909 and 1910 are compared, it is seen that for 1910 the mean is less for average number of kernels per spikelet and greater for average number of spikelets per culm than for 1909.

In regard to the comparative variability of the different characters, there is evidence in the coefficients of variability. From these it is observed that average height, average weight of kernels, and average number of kernels per spikelet, are the least variable characters, the coefficients of these ranging from about 7 to a little more than 16 per cent. In no other instance is the coefficient of variability less than 17, and from this it ranges to nearly 63 per cent.

The average weight of kernels per plant is higher for 1910 than for either of the other two years under consideration, but, since the total and the average number of kernels produced are less, the total and the average yields are still less for 1910. The average number of spikelets per culm per plant also is larger for 1910 than for 1909, but the average number of kernels per spikelet is larger for the latter year. It seems that when development is arrested by environmental conditions, yield is reduced by reduction in number of kernels per plant, per culm, and per spikelet, rather than in average weight of kernels and in number of spikelets produced. The actual kernel weights as given in the correlation tables show that larger kernels were actually produced in 1910 than in the other two years.

Altogether, then, the means indicate that the conditions for growth were not so favorable for the 1910 crop as for those of 1909 and 1912, and resulted in smaller plants and a reduced total yield of grain; but that these smaller plants produced a larger number of spikelets (compared with 1909 only) and larger kernels.

Somewhat different conditions are presented in the year 1908. In the first place, the data were taken on culms only — these being selected from a pure line grown in a drill row — and were taken on these selected culms without reference to the plants from which they came; while in the other

years data are given for the entire plants and the culm is dealt with only in averages for the plants. But, by comparing the data for the culms of 1908 with the averages of the other years, it is seen that in 1908 the culms were not so tall as, and the number of spikelets, number of kernels, and yield were all less than, in the other years, but that the kernels were practically as large as, or larger than, in any other year except 1910. This condition offers evidence corroborative of that given above in regard to the relation of environment to variation.

Coupled with the less plant development and yield of 1908 and 1910, there is less variability, as indicated by the standard deviation, in number of culms, total and average number of kernels, total yield, average number of spikelets, and average number of kernels per spikelet. In average weight of kernels, however, there is greater variability for 1908 and 1910.

CORRELATION

The coefficients expressing the correlation between the different characters under observation are given in Table 4. These coefficients have been determined independently for the four years 1908, 1909, 1910, and 1912. The coefficients expressing the correlation between the same characters are directly comparable for the different years, except in so far as the results may be affected by (1) the use of culms as the unit of measurement in 1908 and of plants as the units in other years, and (2) the methods of growing the plants. The effect of the former has been shown to be small by a study of oats, by Dr. C. E. Leighty, soon to be published as Part II of this series. With reference to the methods of growing the plants, however, it is shown in the study just cited that rather large differences occur in the same variety between the coefficient of correlation determined for plants grown in hills and in drills.

By reference to Table 4 it is seen that the correlation between average height of plant and average weight of kernels per plant varies from $.555 \pm .016$ for 1908 to $-.023 \pm .034$ for 1910 — a considerable variation, which indicates that the correlation between these two characters is not stable nor constant, but fluctuates from year to year.

In contrast to this variation is the correlation between the total yield of plant and the total number of kernels per plant. In this case the coefficient for the different years varies from $.980 \pm .001$ for 1912 to $.918 \pm .005$ for 1910, a difference which is comparatively small.

TABLE 4. COEFFICIENTS OF CORRELATION BETWEEN DIFFERENT CHARACTERS UNDER OBSERVATION

	1908*	1909	1910	1912
Average height of plant in centimeters				
Total yield of plant in grams	....	.689 ± .016	512 ± 025	676 ± 018
Average yield of culm per plant in grams	.710 ± 012	850 ± .008	.745 ± .015	735 ± 016
Total number of kernels per plant	....	.676 ± .016	487 ± 026	662 ± 019
Average number of kernels per culm per plant	658 ± .013	.835 ± .009	.732 ± 016	730 ± 016
Average weight of kernels per plant in milligrams	.555 ± 016	219 ± .029	—.023 ± 034	217 ± 032
Average number of spikelets per culm per plant	.699 ± 012	.817 ± 010	.712 ± .017	.
Number of culms per plant	....	.413 ± .025	.042 ± 034	523 ± .024
Total yield of plant in grams				
Average yield of culm per plant in grams	....	.761 ± .013	.694 ± 017	.692 ± 018
Total number of kernels per plant	947 ± .002	.977 ± 001	918 ± 005	980 ± 001
Average number of kernels per culm per plant	....	.769 ± .012	.680 ± 018	670 ± .019
Average weight of kernels per plant in milligrams	....	.149 ± 029	.035 ± 034	.220 ± 032
Average number of spikelets per culm per plant	.879 ± .005	.767 ± .012	.665 ± 019	...
Number of culms per plant	....	.850 ± 008	.712 ± 017	912 ± .006
Average weight of kernels per plant in milligrams				
Average yield of culm per plant in grams	.464 ± .018	.337 ± .027	.225 ± .032	.429 ± .028
Total number of kernels per plant	....	.033 ± .030	—.253 ± .032	071 ± .034
Average number of kernels per culm per plant	.300 ± 021	.121 ± .030	—.172 ± 033	.087 ± .033
Average number of spikelets per culm per plant	.329 ± 021	.120 ± .030	—.099 ± 033	....
Average number of kernels per spikelet per plant	....	.120 ± 030	—.190 ± 033	....
Number of culms per plant	....	— 021 ± .030	.184 ± 033	050 ± 034
Average number of spikelets per culm per plant				
Average number of kernels per spikelet per plant	....	.324 ± .027	.253 ± 032	......
Number of kernels per culm	.880 ± .005	....	. .	....
Number of culms per plant				
Average yield of culm per plant in grams	....	.387 ± .026	.070 ± 034	383 ± 029
Average number of kernels per culm per plant	....	.423 ± 025	132 ± 033	.408 ± .028

*The data for 1908 are, here and elsewhere, the total per culm, as these, not plants, were the units measured. "Average" and "per plant" should therefore be disregarded for this year.

From the two cases cited above and by an examination of other data contained in Table 4, it seems that correlation may be divided — with only fair accuracy, however — into two classes: (1) those which vary by considerable amount from year to year, and which may be known as fluctuating correlations; and (2) those which are fairly constant from year to year, and which may be known as stable correlations. The distinction between these two classes should be kept in mind in the following pages.

Correlation of average height of plant with other characters

The correlation between average height of plant and total yield of plant (Figs. 1, 2, 3), determined for three years, varies from $.512 \pm .025$

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	
40–45	1														1
45–50	2	1													3
50–55	5	3													8
55–60	1	6	4												11
60–65	7	19	9					1							36
65–70	3	18	26	12	1										60
70–75	4	10	42	20	10	3	2	1		1	1				94
75–80	2	4	14	38	23	6	5	5						2	99
80–85			1	22	32	19	11	10	5			1	1		102
85–90		1		4	13	17	17	9	4	1	2				68
90–95					2	2	5	5	1		2	1			18
	25	62	96	96	81	47	40	31	10	2	5	2	1	2	500

FIG. 1.— *Average height of plant in centimeters, subject*
Total yield of plant in grams, relative. 1909
Coefficient of correlation $= .689 \pm .016$

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	
45–50		1	1							2
50–55	1	6	2							9
55–60	2	6	7	5	1					21
60–65		13	9	9	3					34
65–70		7	46	28	15	1				97
70–75		13	23	43	32	10	2			123
75–80		4	13	20	22	27	2		1	89
80–85			5	3	7	4	3	2		24
85–90										0
90–95				1						1
	3	50	106	109	80	42	7	2	1	400

FIG. 2.— *Average height of plant in centimeters, subject*
Total yield of plant in grams, relative. 1910
Coefficient of correlation $= .512 \pm .025$

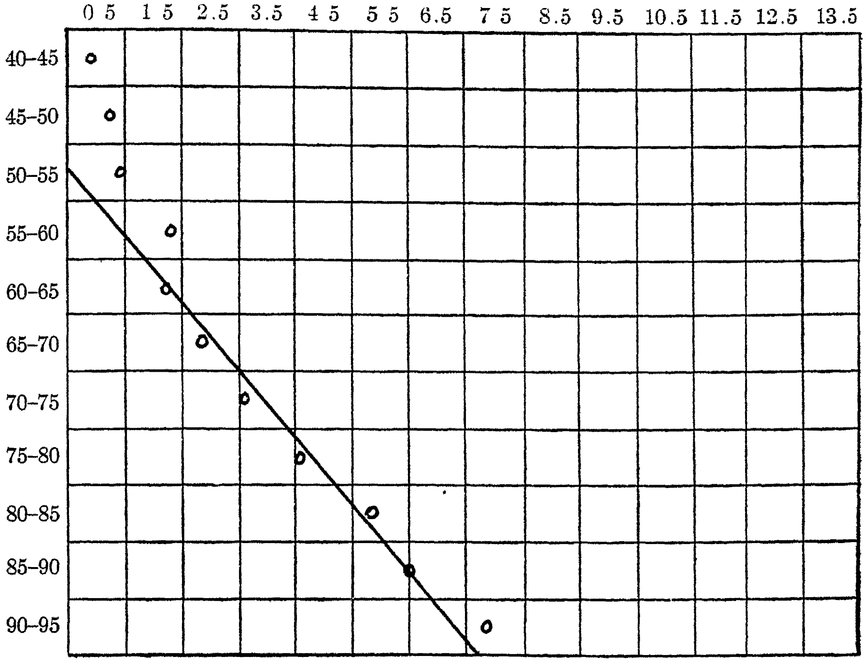

CHART 1.— *Regression for average height of plant and total yield for 1909, from Fig. 1*

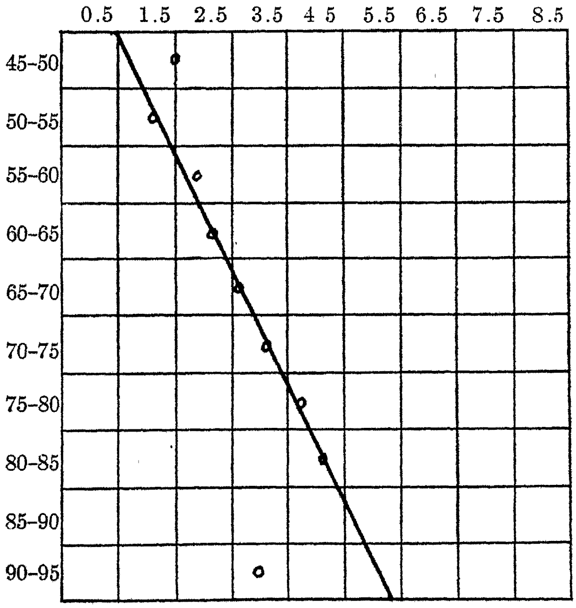

CHART 2.—*Regression for average height of plant and total yield for 1910, from Fig. 2*

	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	
55–60	1	1																		2
60–65		9	1	1																11
65–70		9	13	11	7	4	1													45
70–75	1	1	6	20	14	29	24	24	12	4	2		1	2						140
75–80			1	3	9	25	19	15	18	10	8	7	1	2	1		1	2		122
80–85				2		3	4	6	8	7	17	7	11	2	1	1		1	3	73
85–90									2	2	1		1	1						7
	2	20	21	37	30	61	48	45	40	23	28	14	14	7	2	1	1	3	3	400

FIG. 3.—*Average height of plant in centimeters, subject*
Total yield of plant in grams, relative. 1912
Coefficient of correlation = 676 ± .018

for 1910 to .689±.016 for 1909; while the correlation between average height of plant and average yield of culm per plant (Figs. 4, 5, 6, 7),

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–1 0	1 0–1 1	1 1–1 2	1 2–1 3	1 3–1 4	1 4–1 5	1 5–1 6	1.6–1 7	1.7–1 8	
25–30	4																		4
30–35	6	1																	7
35–40	14	12	1																27
40–45	19	37	18	1	1														76
45–50	5	40	64	27	9	4	2												151
50–55	2	13	60	79	39	30	10	1	2					1					237
55–60		2	12	31	59	39	33	10	4		4	1				1			196
60–65		1	3	7	9	11	18	11	7	5	7		1	2		1			83
65–70			1	3	1	3	4	3	3	3	2	1		1				2	27
70–75		1	1	1		1	2	1		1	3	2	1		1				15
75–80								1		1									2
	50	107	160	149	118	88	69	27	16	10	16	4	2	4	1	2	0	2	825

FIG. 4.—*Height of culm in centimeters, subject*
Total yield of culm in grams, relative. 1908
Coefficient of correlation = .710 ± 012

	.1–.2	.2–.3	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1 0	1 0–1 1	1 1–1.2	1 2–1 3	1 3–1.4	1 4–1 5	1 5–1 6	1.6–1 7	1 7–1.8	1 8–1.9	
40–45	1																		1
45–50	1		1	1															3
50–55		2	4	2															8
55–60		1	2	1	7														11
60–65	1			8	9	9	6	3											36
65–70				2	11	9	26	8	3	1									60
70–75				2	6	13	18	20	17	11	5		1	1					94
75–80						1	6	18	32	21	14	4	1	2					99
80–85								4	12	20	24	22	8	8	2		2		102
85–90									1	4	11	12	17	14	3	3	3		68
90–95										1	1	1	3	2	5	2	2	1	18
	3	3	7	16	33	32	56	53	65	58	55	39	30	27	10	5	7	1	500

FIG. 5.—*Average height of plant in centimeters, subject*
Average yield of culm per plant in grams, relative. 1909
Coefficient of correlation = .850 ± .008

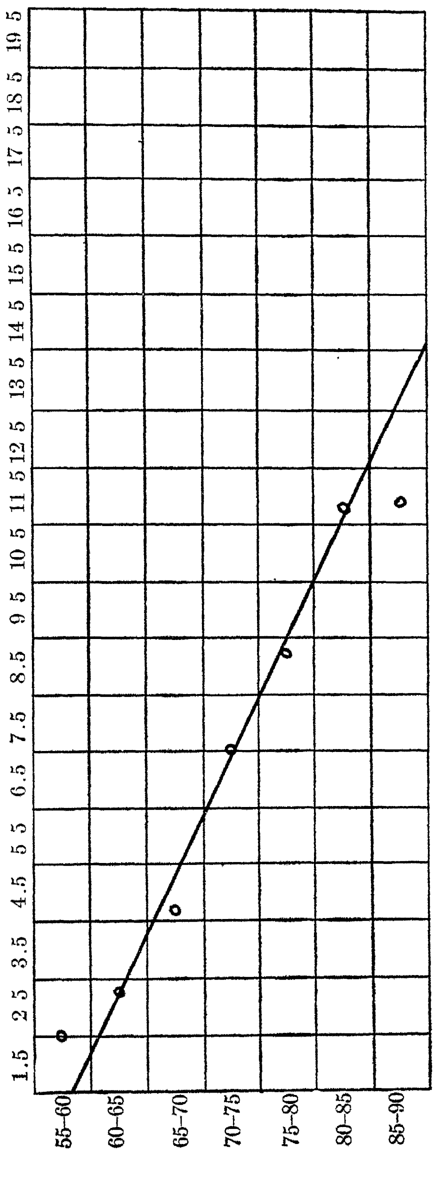

CHART 3.— *Regression for average height of plant and total yield for 1912, from Fig. 3*

	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	
45-50			1	1													2
50-55	3	2	4														9
55-60	1	2	4	8	2	2	1		1								21
60-65		2	6	6	10	5	3	1		1							34
65-70			3	11	21	27	15	10	8	2							97
70-75		1		2	5	23	31	34	17	8	2						123
75-80					3	3	15	16	18	20	11	3					89
80-85						1			5	4	7	5	1			1	24
85-90																	0
90-95													1				1
	4	7	18	28	41	61	65	61	49	35	20	8	2	0	0	1	400

FIG. 6.—*Average height of plant in centimeters, subject*
Average yield of culm per plant in grams, relative. 1910
Coefficient of correlation = .745 ± .015

	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	1.9–2.0	
55-60	1			1												2
60-65		4	3	4												11
65-70			2	11	16	4	9	3								45
70-75			1	5	6	17	35	43	19	10	2	2				140
75-80					2	4	18	32	25	20	9	9	3			122
80-85							3	8	11	20	12	13	4		2	73
85-90											4	1	1	1		7
	1	4	6	21	24	25	65	86	55	50	27	25	8	1	2	400

FIG. 7.—*Average height of plant in centimeters, subject*
Average yield of culm per plant in grams, relative. 1912
Coefficient of correlation = .735 ± .016

determined for four years, varies from .710 ± .012 for 1908 to .850 ± .008 for 1909. It is seen from this that the correlation coefficients in both cases are positive and high and that there is a marked degree of stability from year to year, but that there is at the same time some response to environment. There is a closer relation between culm yield and height than between total yield and height.

The regression lines have been determined for the average height of plant and total yield for the three years 1909, 1910, and 1912. These are shown in Charts 1, 2, and 3.

The correlation between average height of plant and total number of kernels per plant (Figs. 8, 9, 10), determined for three years, varies from .487 ± .026 for 1910 to .676 ± .016 for 1909; while the correlation between average height of plant and average number of kernels per culm per plant (Figs. 11, 12, 13, 14), determined for four years, varies from

	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550	550–600	600–650	650–700	700–750	750–800	
40–45	1																1
45–50	2	1															3
50–55	4	3	1														8
55–60	1	4	6														11
60–65	5	10	15	5						1							36
65–70	3	9	18	18	8	4											60
70–75	3	5	22	34	12	9	4	2	1			2					94
75–80	1	2	5	21	31	17	8	3	5	1	3				1	1	99
80–85			1	8	22	19	21	10	10	4	4	1			2		102
85–90		1		2	6	9	13	11	11	9	4		1	1			68
90–95					1		3	4	3	2	2		1	2			18
	20	35	68	88	80	58	49	30	30	17	13	3	2	3	3	1	500

FIG. 8.— *Average height of plant in centimeters, subject*
Total number of kernels per plant, relative. 1909
Coefficient of correlation = .676 ± .016

	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	
45–50		1	1								2
50–55		3	4	2							9
55–60	2	4	8	3	4						21
60–65		6	13	8	5	2					34
65–70		3	30	32	21	9	2				97
70–75		4	25	29	34	19	7	5			123
75–80			11	17	13	25	19	2	1	1	89
80–85			3	4	4	3	5	1	3	1	24
85–90											0
90–95				1							1
	2	21	95	96	81	58	33	8	4	2	400

FIG. 9.— *Average height of plant in centimeters, subject*
Total number of kernels per plant, relative. 1910
Coefficient of correlation = .487 ± .026

	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550	550–600	600–650	650–700	700–750	750–800	800–850	850–900	900–950	950–1000	1000–1050	1050–1100	1100–1150	1150–1200	1200–1250	1250–1300	
55–60	2																								2
60–65		9	1	1																					11
65–70		7	7	9	8	3	6	5																	45
70–75	1	1	4	5	17	11	19	19	14	20	13	7	4	1	1	1	1	1							140
75–80			1		5	9	13	15	15	9	10	12	8	7	7	2	2	3			3	1			122
80–85				1	1	1	2	1	6	3	4	7	6	5	12	8	4	6		1	1	1	1	2	73
85–90											2	1	1	1			1	1							7
	3	17	13	16	31	24	40	40	35	32	29	27	19	14	20	11	8	11	0	1	4	2	1	2	400

FIG. 10.— *Average height of plant in centimeters, subject*
Total number of kernels per plant, relative. 1912
Coefficient of correlation = .662 ± .019

	1–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
25–30	4										4
30–35	6	1									7
35–40	21	6									27
40–45	43	30	2	1							76
45–50	21	97	26	6		1					151
50–55	9	97	95	32	2	1			1		237
55–60	1	24	94	53	16	4	3		1		196
60–65	1	7	16	31	17	5	3	2	1		83
65–70		3	5	6	6	3		2		2	27
70–75		3		2	4	4	1	1			15
75–80				1	1						2
	106	268	238	132	46	18	7	·5	3	2	825

FIG. 11.—*Height of culm in centimeters, subject*
Total number of kernels per culm, relative. 1908
Coefficient of correlation = .658 ± .013

	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	100–110	110–120	
40–45	1											1
45–50	1	2										3
50–55	3	4	1									8
55–60	1	3	7									11
60–65		7	13	14	2							36
65–70		1	13	27	18			1				60
70–75		1	9	38	27	16	2	1				94
75–80			1	7	43	31	16	1				99
80–85				1	14	35	33	16	2	1		102
85–90					4	6	21	24	10	3		68
90–95							4	5	5	3	1	18
	6	18	44	87	108	88	76	48	17	7	1	500

FIG. 12.—*Average height of plant in centimeters, subject*
Average number of kernels per culm per plant, relative. 1909
Coefficient of correlation = .835 ± .009

.658±.013 for 1908 to .835±.009 for 1909. In each case the correlation coefficients are positive, high, and fairly stable. This indicates that height and kernels produced depend on each other to a considerable extent, but that the relation may be modified by environmental conditions. There is a closer relation between height and kernel production for the average culm than for the whole plant.

	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
45–50		2							2
50–55	5	3	1						9
55–60	6	8	5	1	1				21
60–65	2	9	18	4	1				34
65–70		9	41	33	12	2			97
70–75		2	28	45	34	13	1		123
75–80			3	26	27	24	9		89
80–85				1	2	12	6	3	24
85–90									0
90–95							1		1
	13	33	96	110	77	51	17	3	400

FIG. 13.— *Average height of plant in centimeters, subject*
Average number of kernels per culm per plant, relative. 1910
Coefficient of correlation = .732 ± .016

	30–40	40–50	50–60	60–70	70–80	80–90	90–100	100–110	110–120	120–130	
55–60	1		1								2
60–65		4	7								11
65–70			7	22	9	6	1				45
70–75			1	13	30	59	32	5			140
75–80				2	16	40	38	23	3		122
80–85					1	12	26	23	9	2	73
85–90								3	2	2	7
	1	4	16	37	56	117	97	54	14	4	400

FIG. 14.— *Average height of plant in centimeters, subject*
Average number of kernels per culm per plant, relative. 1912
Coefficient of correlation = .730 ± .016

The correlation between average height of plant and average weight of kernels per plant (Figs. 15, 16, 17, 18), determined for four years, varies from $-.023 \pm .034$ for 1910 to $.555 \pm .016$ for 1908. This correlation is fluctuating and ranges from what is virtually no correlation to a high correlation. From this it must be concluded that the relation between height of plant and average weight of kernels is occasionally close, but that it is responsive to, and is modified by, environment to such an extent that sometimes the two characters may be practically independent of each other.

	3.5–4.5	4.5–5.5	5.5–6.5	6.5–7.5	7.5–8.5	8.5–9.5	9.5–10.5	10.5–11.5	11.5–12.5	12.5–13.5	13.5–14.5	14.5–15.5	15.5–16.5	16.5–17.5	17.5–18.5	18.5–19.5	19.5–20.5	20.5–21.5	21.5–22.5	22.5–23.5	23.5–24.5	24.5–25.5	25.5–26.5	26.5–27.5	27.5–28.5	28.5–29.5	29.5–30.5	
25–30	1			1		1											1											4
30–35	1	1				1	2				2																	7
35–40		1			1		1		5	6	5	3	4	1														27
40–45					1		1	2	2	7	14	17	17	6	4	1	2	1				1						76
45–50							1	3	2	3	12	27	31	21	24	17	9						1					151
50–55											5	33	43	64	48	22	16	1	3	1	1							237
55–60								1				11	28	50	43	36	15	3	2	4	1			1			1	196
60–65				1								2	2	17	13	20	12	10	4	1	1							83
65–70													2	2	5	8	2	4	1	2	1							27
70–75								1					1	1	1	3	1	2	3	2								15
75–80																	1			1								2
	2	2	0	2	2	2	5	7	9	16	38	93	128	162	138	107	59	21	13	11	4	1	1	1	0	0	1	825

FIG. 15.—*Height of culm in centimeters, subject*
Average weight of kernels per culm in milligrams, relative. *1908*
Coefficient of correlation = *.555* ± *.016*

	8.5–9.5	9.5–10.5	10.5–11.5	11.5–12.5	12.5–13.5	13.5–14.5	14.5–15.5	15.5–16.5	16.5–17.5	17.5–18.5	18.5–19.5	19.5–20.5	
40–45								1					1
45–50			1				2						3
50–55						1	3	2	1	1			8
55–60						2	3	5	1				11
60–65	1	1			1	3	7	10	9	4			36
65–70				2	1	5	13	20	16	3			60
70–75	1		1			1	19	36	23	8	5		94
75–80						3	27	32	26	8	3		99
80–85						2	11	40	37	9	2	1	102
85–90				1		1	7	28	21	5	5		68
90–95					1		1	11	4		1		18
	2	1	2	3	3	18	93	185	138	38	16	1	500

FIG. 16.— *Average height of plant in centimeters, subject*
Average weight of kernels per plant in milligrams, relative. *1909*
Coefficient of correlation = .219 ± .029

	11.5–12.5	12.5–13.5	13.5–14.5	14.5–15.5	15.5–16.5	16.5–17.5	17.5–18.5	18.5–19.5	19.5–20.5	20.5–21.5	21.5–22.5	22.5–23.5	23.5–24.5	
45–50							1	1						2
50–55		1	2	1	1	3			1					9
55–60			1	1	3	7	4	2	1	1	1			21
60–65		1	1	3	7	8	10	2		1	1			34
65–70		1	5	'13	13	24	23	9	5	2	1		1	97
70–75		1	3	12	31	30	24	11	5	5	1			123
75–80	1		3	16	14	25	13	10	6	1				89
80–85			1	4	3	6	7	2	1					24
85–90														0
90–95							1							1
	1	4	16	50	72	103	83	37	19	10	4	0	1	400

FIG. 17.— *Average height of plant in centimeters, subject*
Average weight of kernels per plant in milligrams, relative. *1910*
Coefficient of correlation = —.023 ± .034

	12	13	14	15	16	17	18	19	
55–60				2					2
60–65		2	5	3	1				11
65–70	1	12	22	8	2				45
70–75	3	27	52	43	10	2	2	1	140
75–80		11	50	42	15	3		1	122
80–85	1	2	25	28	14	2	1		73
85–90			4	2		1			7
	5	54	158	128	42	8	3	2	400

FIG. 18.— *Average height of plant in centimeters, subject*
Average weight of kernels per plant in milligrams, relative. *1912*
Coefficient of correlation = .217 ± .032

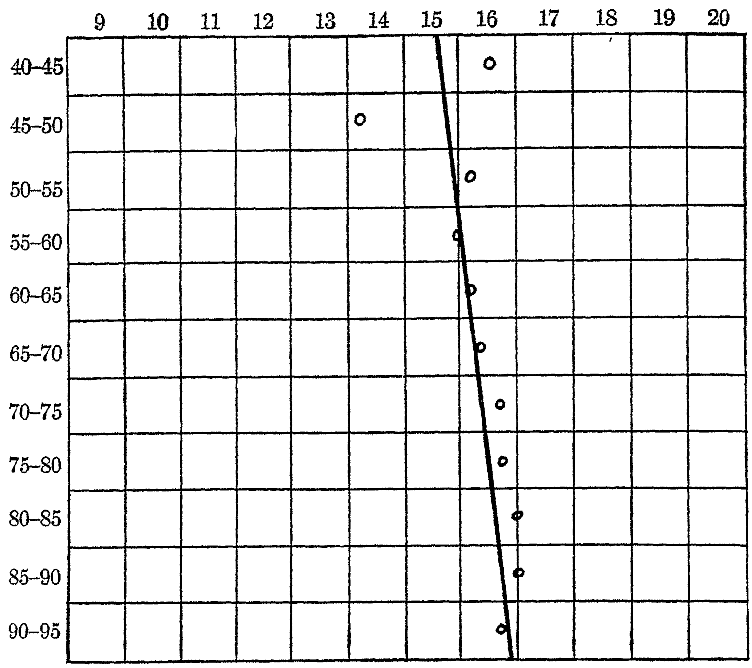

CHART 4.— *Regression for average height of plant and average weight of kernels for 1909, from Fig. 16*

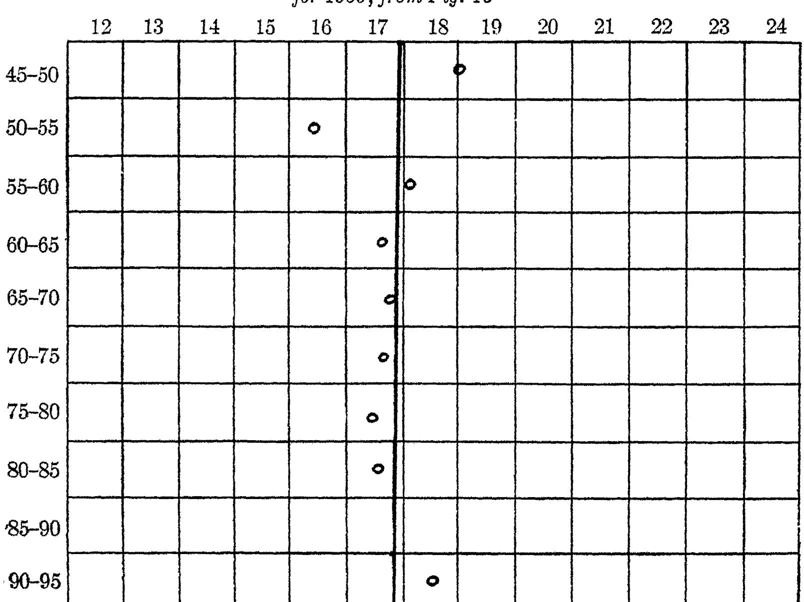

CHART 5.—*Regression for average height of plant and average weight of kernels for 1910, from Fig. 17*

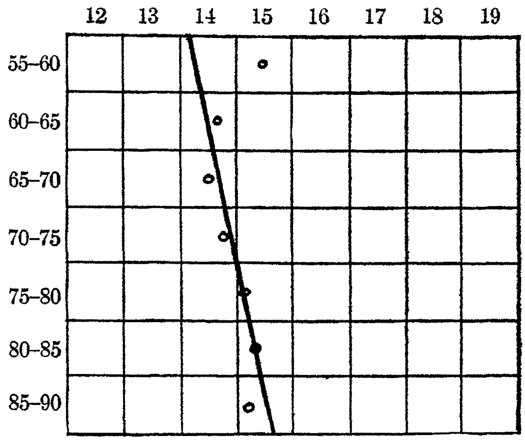

CHART 6.— *Regression for average height of plant and average weight of kernels for 1912, from Fig. 18*

The regression lines have been determined for the average height of plant and average weight of kernels for the three years 1909, 1910, and 1912. These are shown in Charts 4, 5, and 6.

The correlation between average height of plant and average number of spikelets per culm per plant (Figs. 19, 20, 21), determined for three

	1–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	
25–30	3	1									4
30–35	5	1	1								7
35–40	9	15	2	1							27
40–45	13	50	11	2							76
45–50	3	74	55	15	3		1				151
50–55		35	101	66	30	4		1			237
55–60		9	36	76	48	21	4	2			196
60–65		1	7	18	30	18	5	4			83
65–70			2	7	5	7	3		2	1	27
70–75				2	5	6	1		1		15
75–80					2						2
	33	186	215	187	123	56	14	7	3	1	825

FIG. 19.— *Height of culm in centimeters, subject*
Number of spikelets per culm, relative. *1908*
Coefficient of correlation = .699 ± .012

	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	
40–45	1									**1**
45–50	1	1	1							**3**
50–55	2	5	1							**8**
55–60	2	4	5							11
60–65	2	10	16	6	2					36
65–70		7	10	34	8	1				60
70–75		1	18	37	27	9	2			94
75–80			6	16	43	29	5			99
80–85				6	29	42	20	5		102
85–90				1	6	20	29	11	1	68
90–95						1	5	10	2	18
	8	28	57	100	115	102	61	26	3	500

Fig. 20.— *Average height of plant in centimeters, subject*
Average number of spikelets per culm per plant, relative. ***1909***
Coefficient of correlation = .817 ± .010

	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	
45–50		1	1						**2**
50–55	3	5	1						**9**
55–60	4	8	5	2		2			21
60–65	2	5	15	9	3				34
65–70		2	26	37	24	5	3		97
70–75			11	37	48	23	4		123
75–80				11	35	27	12	4	89
80–85				1	2	9	8	4	24
85–90									0
90–95							1		1
	9	21	59	97	112	66	28	8	400

Fig. 21.— *Average height of plant in centimeters, subject*
Average number of spikelets per culm per plant, relative. ***1910***
Coefficient of correlation = .712 ± .017

years, varies from .699±.012 for 1908 to .817±.010 for 1909. The correlation is fairly stable and very high. From this it may be concluded that the number of spikelets produced is largely dependent on the vigor of the plant as expressed in height of culm, the taller plants tending very strongly to produce large numbers of spikelets.

The correlation between average height of plant and number of culms per plant (Figs. 22, 23, 24), determined for three years, varies from

	1	2	3	4	5	6	7	8	9	10	11	
40–45		1										1
45–50	1	1	1									3
50–55		5		3								8
55–60		2	3	5	1							11
60–65	3	13	11	8					1			36
65–70	3	8	27	15	7							60
70–75	3	12	29	35	8	3	3	1				94
75–80	2	6	22	45	10	3	7	2	1		1	99
80–85		2	15	48	16	13	6	2				102
85–90	1		6	31	17	11	2					68
90–95			1	8	5	1	1	2				18
	13	50	115	198	64	31	19	7	2	0	1	500

FIG. 22.— *Average height of plant in centimeters, subject Number of culms per plant, relative. 1909 Coefficient of correlation = .413 ± .025*

	2	3	4	5	6	7	
45–50		1	1				2
50–55	2	3	3			1	9
55–60	4	9	4	2	2		21
60–65	6	10	13	4	1		34
65–70	8	40	42	6	1		97
70–75	15	41	53	12	2		123
75–80	10	22	43	11	3		89
80–85	4	8	8	3	1		24
85–90							0
90–95	1						1
	50	134	167	38	10	1	400

FIG. 23.— *Average height of plant in centimeters, subject Number of culms per plant, relative. 1910 Coefficient of correlation = .042 ± .034*

	2	3	4	5	6	7	8	9	10	11	12	13	14	
55–60	1		1											2
60–65		6	3	2										11
65–70	1	10	17	9	6	2								45
70–75	2	5	24	32	31	26	15	3	2					140
75–80		2	14	29	15	18	32	7	1	3			1	122
80–85		2	2	6	5	14	22	12	6	2	2			73
85–90					4	1	1	1						7
	4	25	61	78	61	61	70	23	9	5	2	0	1	400

FIG. 24.— *Average height of plant in centimeters, subject Number of culms per plant, relative. 1912 Coefficient of correlation = .523 ± .024*

.042±.034 for 1910 to .523±.024 for 1912. This correlation, like the one just considered, is fluctuating and ranges from no correlation to a high correlation. And in the same way it must be concluded that the correlation which exists between the height of plant and the number of culms produced by that plant is strong under some conditions, but that it is responsive to, and is modified by, environment to such an extent that on occasion the two characters may be practically independent of each other.

Considering the relation of average height of plant to the other plant characters as a whole, it has been shown that there is generally a very high, positive, and stable correlation between the average height of plant and (1) total and average yield, (2) total and average number of kernels produced, (3) average number of spikelets per culm. These relations are disturbed to some extent by environmental conditions such as exist in different years. It is conceivable that they might vary to a greater extent, even to such a degree that there would be no correlation between these characters. Under very abnormal weather conditions which would allow vegetative development to some extent but under which grain development would be prohibited, correlations would be impossible; but correlations such as those mentioned above are likely to obtain in any case when kernels are produced in sufficient quantity to render possible the determination of averages. Whenever kernels are developed, the taller plants would tend to develop the greater numbers of spikelets and kernels, and consequently to produce the higher yields.

The correlation of average height with the averages per culm are higher than those with the plant totals. This is undoubtedly due to the fact that height itself is an average, and when averages are used there has been effected a similar and simultaneous change in both the height and the other character under consideration.

The correlations between height of plant and (1) average weight of kernels, (2) number of culms, are fluctuating in amount, occasionally being high, but being influenced by environmental conditions from year to year so that the relation of one to the other may become such that they vary independently. A short plant, then, on occasion may develop as large kernels as a tall plant, or may develop as many culms.

Correlation of total yield of plant with other characters

The correlation between total yield of plant and average yield of culm per plant (Figs. 25, 26, 27), determined for three years, varies from .692±.018 for 1912 to .761±.013 for 1909. This correlation is very high, positive, and stable — as would be expected, in fact. It is not by any means perfect correlation, however, this being due to the method of development in the oat plant. All culms do not develop equally,

	.1–.2	.2–.3	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	
0– 1	3	3	3	6	1	3	3	3											25
1– 2			4	10	22	8	7	5	5								1		62
2– 3					10	18	28	20	12	4	2		1	1					96
3– 4						3	15	17	29	14	12	5					1		96
4– 5							3	4	12	27	22	7		4	2				81
5– 6									2	6	7	11	11	10					47
6– 7								3	4		5	7	10		5	3	3		40
7– 8								1	1	6	5	8	1	5	3			1	31
8– 9										1		1	4	3		1			10
9–10											1		1						2
10–11													1	2		1	1		5
11–12													1	1					2
12–13																	1		1
13–14											1			1					2
	3	3	7	16	33	32	56	53	65	58	55	39	30	27	10	5	7	1	500

FIG. 25.— *Total yield of plant in grams, subject*
Average yield of culm per plant in grams, relative. 1909
Coefficient of correlation = .761 ± .013

	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	
0–1	1	1					1										3
1–2	2	5	13	9	5	6	10										50
2–3	1	1	5	13	25	25	18	6	5	4	2	1					106
3–4				5	9	24	28	16	18	7	1		1				109
4–5				1	2	6	6	31	17	10	3	3	1				80
5–6							2	7	7	11	13	2					42
6–7								1	2	3	1						7
7–8												1				1	2
8–9												1					1
	4	7	18	28	41	61	65	61	49	35	20	8	2	0	0	1	400

FIG. 26.— *Total yield of plant in grams, subject*
Average yield of culm per plant in grams, relative. 1910
Coefficient of correlation = .694 ± .017

	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	1.9–2.0	
1–2				2												2
2–3	1	3	4	9	1			2								20
3–4		1	2	4	7	3	3	1								21
4–5				3	6	8	11	5	2	1		1				37
5–6					4	1	13	5	2	5						30
6–7				1	4	4	10	20	13		5	3	1			61
7–8				2	2	6	5	13	3	12	5					48
8–9						3	12	11	8	7		3	1			45
9–10							8	13	12	1	4	2				40
10–11							1	9	6	4	2		1			23
11–12							1	5	5	12		4		1		28
12–13									1	5	5	3				14
13–14								1	3	2	3	4			1	14
14–15								1		1	2	2	1			7
15–16							1				1					2
16–17												1				1
17–18													1			1
18–19												1	2			3
19–20												1	1		1	3
	1	4	6	21	24	25	65	86	55	50	27	25	8	1	2	400

FIG. 27.— *Total yield of plant in grams, subject*
Average yield of culm per plant in grams, relative. *1912*
Coefficient of correlation = .692 ± .018

	1–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
*0–.1	50										50
.1–.2	54	53									107
.2–.3	2	154	3		1						160
.3–.4		56	93								149
.4–.5		5	109	4							118
.5–.6			29	55	2	2					88
.6–.7			4	59	6						69
.7–.8				11	16						27
.8–.9				3	11	2					16
.9–1.0					6	4					10
1.0–1.1					3	7	5	1			16
1.1–1.2					1	2	1				4
1.2–1.3						1	1				2
1.3–1.4								3	1		4
1.4–1.5								1			1
1.5–1.6									2		2
1.6–1.7											0
1.7–1.8										2	2
	106	268	238	132	46	18	7	5	3	2	825

FIG. 28.— *Total yield of culm in grams, subject*
Total number of kernels per culm, relative. *1908*
Coefficient of correlation = .947 ± .002

*Since, as before noted, the data were taken on culms this year, the classes for yield differ from those of the other years.

some being much less important than others, and the average yield of those making up a plant is therefore not related absolutely to the total yield of the plant.

The correlation between total yield of plant and total number of kernels per plant (Figs. 28, 29, 30, 31), determined for four years, varies from

	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550	550–600	600–650	650–700	700–750	750–800	
0– 1	20	4	1														25
1– 2		31	30	1													62
2– 3			37	58	1												96
3– 4				29	59	8											96
4– 5					20	47	14										81
5– 6						3	34	9		1							47
6– 7							1	21	18								40
7– 8									12	15	4						31
8– 9										1	8	1					10
9–10											1	1					2
10–11												1	2	2			5
11–12														1	1		2
12–13															1		1
13–14															1	1	2
	20	35	68	88	80	58	49	30	30	17	13	3	2	3	3	1	500

FIG. 29.— *Total yield of plant in grams, subject*
Total number of kernels per plant, relative. *1909*
Coefficient of correlation = .977 ± .001

	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	
0–1	2	1									3
1–2		20	30								50
2–3			61	45							106
3–4			4	47	51	7					109
4–5				4	30	39	7				80
5–6						12	26	4			42
6–7								3	4		7
7–8								1		1	2
8–9										1	1
	2	21	95	96	81	58	33	8	4	2	400

FIG. 30.— *Total yield of plant in grams, subject*
Total number of kernels per plant, relative. *1910*
Coefficient of correlation = .918 ± .005

	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550	550–600	600–650	650–700	700–750	750–800	800–850	850–900	900–950	950–1000	1000–1050	1050–1100	1100–1150	1150–1200	1200–1250	1250–1300	
1–2	2																								2
2–3	1	17	2																						20
3–4			11	10																					21
4–5				6	25	5	1																		37
5–6					5	13	11	1																	30
6–7					1	5	26	25	4																61
7–8						1	2	14	18	10	3														48
8–9									12	19	13	1													45
9–10									1	3	11	18	6	1											40
10–11											2	7	8	6											23
11–12												1	5	6	13	2		1							28
12–13														1	6	5	1	1							14
13–14															1	3	4	6							14
14–15																1	3	3							7
15–16																				1	1				2
16–17																					1				1
17–18																					1				1
18–19																					1	1	1		3
19–20																						1		2	3
	3	17	13	16	31	24	40	40	35	32	29	27	19	14	20	11	8	11	0	1	4	2	1	2	400

FIG. 31.— *Total yield of plant in grams, subject*
Total number of kernels per plant, relative. *1912*
Coefficient of correlation = .980 ± .001

.918±.005 for 1910 to .980±.001 for 1912; while that between total yield and average number of kernels per culm per plant (Figs. 32, 33, 34), determined for three years, varies from .670±.019 for 1912 to .769±.012 for 1909. These correlations are very high, especially those between the totals, and are stable from year to year. In fact, since the total

	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	100–110	110–120	
0– 1	6	7	3	8	1							25
1– 2		11	27	15	6	2			1			62
2– 3			14	41	30	9	2					96
3– 4				19	45	22	9	1				96
4– 5				2	19	37	15	8				81
5– 6					2	9	15	18	3			47
6– 7				1	4	4	13	8	7	3		40
7– 8				1	1	5	15	3	5		1	31
8– 9							2	7		1		10
9–10							2					2
10–11							1	1	1	2		5
11–12								2				2
12–13										1		1
13–14							2					2
	6	18	44	87	108	88	76	48	17	7	1	500

FIG. 32.— *Total yield of plant in grams, subject*
Average number of kernels per culm per plant, relative. *1909*
Coefficient of correlation = *.769 ± .012*

	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
0–1	3								3
1–2	7	17	13	9	3	1			50
2–3	2	13	47	31	8	3	2		106
3–4	1	2	27	45	29	4	1		109
4–5		1	9	19	28	20	2	1	80
5–6				6	8	18	10		42
6–7					1	4	2		7
7–8								2	2
8–9						1			1
	13	33	96	110	77	51	17	3	400

FIG. 33.— *Total yield of plant in grams, subject*
Average number of kernels per culm per plant, relative. *1910*
Coefficient of correlation = *.680 ± .018*

	30– 40	40– 50	50– 60	60– 70	70– 80	80– 90	90–100	100–110	110–120	120–130	
1– 2			1	1							2
2– 3	1	3	11	3	1	1					20
3– 4		1	2	12	4	2					21
4– 5			2	5	13	11	4	2			37
5– 6				4	8	12	4	2			30
6– 7				6	10	22	18	4	1		61
7– 8				4	7	18	12	7			48
8– 9				1	9	15	15	5			45
9–10					3	19	14	3	1		40
10–11				1		7	11	3	1		23
11–12						6	9	10	2	1	28
12–13						1	5	6	2		14
13–14						2	3	5	1	3	14
14–15						1	2	3	1		7
15–16					1			1			2
16–17									1		1
17–18									1		1
18–19								1	2		3
19–20								2	1		3
	1	4	16	37	56	117	97	54	14	4	400

FIG. 34.— *Total yield of plant in grams, subject*
Average number of kernels per culm per plant, relative. *1912*
Coefficient of correlation = *.670* ± *.019*

	8.5– 9.5	9.5–10.5	10.5–11.5	11.5–12.5	12.5–13.5	13.5–14.5	14.5–15.5	15.5–16.5	16.5–17.5	17.5–18.5	18.5–19.5	19.5–20.5	
0– 1	1	1	1			1	3	9	6	3			25
1– 2	1			1		6	13	20	18	2	1		62
2– 3			1	1	2	3	26	36	17	8	2		96
3– 4						5	17	32	31	5	5	1	96
4– 5					1	2	12	27	21	13	5		81
5– 6				1			7	17	20	2			47
6– 7						1	8	17	9	3	2		40
7– 8							5	16	9	1			31
8– 9							1	6	3				10
9–10								1	1				2
10–11							1	2	1		1		5
11–12								2					2
12–13									1				1
13–14									1	1			2
	2	1	2	3	3	18	93	185	138	38	16	1	500

FIG. 35.— *Total yield of plant in grams, subject*
Average weight of kernels per plant in milligrams, relative. *1909*
Coefficient of correlation = *.149* ± *.029*

	11.5–12.5	12.5–13.5	13.5–14.5	14.5–15.5	15.5–16.5	16.5–17.5	17.5–18.5	18.5–19.5	19.5–20.5	20.5–21.5	21.5–22.5	22.5–23.5	23.5–24.5	
0–1			1			1	1							3
1–2	1	3	2	5	12	13	10	2	2					50
2–3			5	13	14	31	23	11	6	2	1			106
3–4		1	4	9	23	20	26	13	6	5	2			109
4–5			2	15	15	18	16	6	3	3	1		1	80
5–6			1	6	5	18	7	4	1					42
6–7			1	1	3	2								7
7–8				1					1					2
8–9								1						1
	1	4	16	50	72	103	83	37	19	10	4	0	1	400

FIG. 36.— *Total yield of plant in grams, subject*
Average weight of kernels per plant in milligrams, relative. *1910*
Coefficient of correlation = *.035 ± .034*

	11.5–12.5	12.5–13.5	13.5–14.5	14.5–15.5	15.5–16.5	16.5–17.5	17.5–18.5	18.5–19.5	
1– 2			1	1					2
2– 3		4	11	4	1				20
3– 4		7	6	7	1				21
4– 5	2	10	15	10					37
5– 6	2	2	10	11	4		1		30
6– 7		5	29	15	9	2		1	61
7– 8		11	16	14	5		1	1	48
8– 9		5	18	14	8				45
9–10		6	17	12	3	1	1		40
10–11		1	10	10		2			23
11–12	1	2	13	7	4	1			28
12–13		1	4	7	2				14
13–14			6	6	2				14
14–15				6	1				7
15–16			2						2
16–17				1					1
17–18				1					1
18–19				1	1	1			3
19–20				1	1	1			3
	5	54	158	128	42	8	3	2	400

FIG. 37.— *Total yield of plant in grams, subject*
Average weight of kernels per plant in milligrams, relative. *1912*
Coefficient of correlation = *.220 ± .032*

yield is made up of the total number of kernels, such a condition is to be expected unless excessive variation in size of kernels should exist; which is not the case, as kernel weight is one of the least variable characters. The higher correlation of total yield with total number of kernels than with average number of kernels per culm results from the process of averaging, since there are a number of low-producing culms whose results affect the average yield per culm for many of the plants.

The correlation between total yield of plant and average weight of kernels per plant (Figs. 35, 36, 37), determined for three years, varies from $.035 \pm .034$ for 1910 to $.220 \pm .032$ for 1912. This correlation is fluctuating, and never very high, which indicates that large kernels are obtained from plants either low or high in yield in about the same proportions. In other words, the kernels produced by plants whether of large or small yield do not vary considerably in average size.

The correlation between total yield of plant and average number of spikelets per culm per plant (Figs. 38, 39, 40), determined for three years,

	1–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	
*0– .1	25	21	4								50
.1– .2	8	83	10	4	2						107
.2– .3		72	78	4	6						160
.3– .4		9	94	40	5	1					149
.4– .5		1	26	82	8	1					118
.5– .6			3	40	40	4	1				88
.6– .7				15	39	15					69
.7– .8				1	11	14	1				27
.8– .9				1	6	6	3				16
.9–1.0					3	6	1				10
1.0–1.1					2	6	6	2			16
1.1–1.2					1	1	1	1			4
1.2–1.3						1	1				2
1.3–1.4						1		2	1		4
1.4–1.5									1		1
1.5–1.6								2			2
1.6–1.7											0
1.7–1.8									1	1	2
	33	186	215	187	123	56	14	7	3	1	825

FIG. 38.— *Total yield of culm in grams, subject*
Average number of spikelets per culm, relative. 1908
Coefficient of correlation = $.879 \pm .005$

*Since, as before noted, the data were taken on culms this year, the classes for yield differ from those of the other years.

	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	
0– 1	7	7	7	3	1					25
1– 2	1	19	23	15	2	1	1			62
2– 3		2	23	45	23	2	1			96
3– 4			3	31	44	16	2			96
4– 5				4	30	34	10	3		81
5– 6			1		4	20	19	3		47
6– 7				2	6	9	16	6	1	40
7– 8					5	15	4	6	1	31
8– 9						3	4	3		10
9–10							2			2
10–11						1	1	2	1	5
11–12								2		2
12–13								1		1
13–14						1	1			2
	8	28	57	100	115	102	61	26	3	500

FIG. 39.— *Total yield of plant in grams, subject*
Average number of spikelets per culm per plant, relative. 1909
Coefficient of correlation = .767 ± .012

	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	
0–1	3								3
1–2	4	13	14	11	6	1		1	50
2–3	2	7	30	40	19	6	2		106
3–4		1	13	31	45	16	3		109
4–5			2	15	33	20	9	1	80
5–6					9	18	11	4	42
6–7						4	2	1	7
7–8							1	1	2
8–9						1			1
	9	21	59	97	112	66	28	8	400

FIG. 40.— *Total yield of plant in grams, subject*
Average number of spikelets per culm per plant, relative. 1910
Coefficient of correlation = .665 ± .019

varies from $.665 \pm .019$ for 1910 to $.879 \pm .005$ for 1908. This correlation is very high, positive, and fairly stable. It indicates that the total yield is dependent to a large extent on the number of spikelets produced. The correlation of yield and total number of spikelets would undoubtedly be higher than that with average number of spikelets per culm.

The correlation between total yield of plant and number of culms per plant (Figs. 41, 42, 43), determined for three years, varies from .712±.017

	1	2	3	4	5	6	7	8	9	10	11	
0– 1	12	13										25
1– 2	1	28	24	8	1							62
2– 3		8	54	34								96
3– 4		1	31	56	8							96
4– 5			6	56	16	3						81
5– 6				32	13	2						47
6– 7				11	17	5	6	1				40
7– 8				1	8	12	8	1	1			31
8– 9					1	7	1	1				10
9–10							1	1				2
10–11						2	2	1				5
11–12								2				2
12–13							1					1
13–14									1		1	2
	13	50	115	198	64	31	19	7	2	0	1	500

FIG. 41.—*Total yield of plant in grams, subject*
Number of culms per plant, relative. 1909
Coefficient of correlation = .850 ± .008

	2	3	4	5	6	7	
0–1	3						3
1–2	28	19	3				50
2–3	18	66	20	1		1	106
3–4	1	42	58	7	1		109
4–5		7	59	11	3		80
5–6			26	14	2		42
6–7				4	3		7
7–8			1	1			2
8–9					1		1
	50	134	167	38	10	1	400

FIG. 42.—*Total yield of plant in grams, subject*
Number of culms per plant, relative. 1910
Coefficient of correlation = .712 ± .017

for 1910 to .912±.006 for 1912. This is positive, very high, and fairly stable. It indicates that as the number of culms per plant increases there is a very marked increase in the total yield of grain, or that the total yield of grain is highly responsive to the culm production of the plant.

	2	3	4	5	6	7	8	9	10	11	12	13	14	
1- 2	2													2
2- 3	2	14	4											20
3- 4		7	12	2										21
4- 5		4	24	8	1									37
5- 6			12	14	4									30
6- 7			9	33	15	4								61
7- 8				17	18	9	4							48
8- 9				4	15	22	4							45
9-10					6	15	19							40
10-11					1	6	15	1						23
11-12					1	4	15	7	1					28
12-13							8	6						14
13-14						1	4	5	3	1				14
14-15							1	4	1		1			7
15-16									1				1	2
16-17									1					1
17-18									1					1
18-19										3				3
19-20									1	1	1			3
	4	25	61	78	61	61	70	23	9	5	2	0	1	400

FIG. 43.— *Total yield of plant in grams, subject*
Number of culms per plant, relative. 1912
Coefficient of correlation $= .912 \pm .006$

Considering the relation of total yield of plant to other plant characters, it must be concluded that increase in yield must be accompanied by increase in (1) culm yield, (2) kernel production, both total and average, (3) average spikelet production, and (4) culm production; while, on the other hand, the average weight of kernels is practically independent of yield.

Correlation of average weight of kernels per plant with other characters

The correlation between average weight of kernels per plant and average yield of culm per plant (Figs. 44, 45, 46, 47), determined for four years, varies from $.225 \pm .032$ for 1910 to $.464 \pm .018$ for 1908. This correlation is not very high and fluctuates considerably. It is higher, however, than that between the average weight of kernels and total yield of plant, as noted above. These facts indicate that the large kernels are produced to an appreciable extent on those plants whose culms produce high yields

	0–.1	.1–.2	.2–.3	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	
3.5– 4.5	2																		2
4.5– 5.5	2																		2
5.5– 6.5																			0
6.5– 7.5	1		1																2
7.5– 8.5	1	1																	2
8.5– 9.5	2																		2
9.5–10.5	4					1													5
10.5–11.5		4	1			2													7
11.5–12.5	7	1	1																9
12.5–13.5	7	7	2																16
13.5–14.5	4	19	13	2															38
14.5–15.5	10	24	26	21	6	4	2												93
15.5–16.5		22	35	38	14	11	4	3			1								128
16.5–17.5	5	10	34	33	32	20	16	5	2		4			1					162
17.5–18.5	1	7	25	27	24	23	14	7	1	3	3	1		1				1	138
18.5–19.5		7	8	16	26	15	13	6	7	1	2			2	1	2		1	107
19.5–20.5	4	2	10	5	8	7	14	2	2	2	1	1	1						59
20.5–21.5			3		4	2	2	2	2	2	3		1						21
21.5–22.5		1		5		1	2			2	1	1							13
22.5–23.5		1		1	1	2	2	2	1			1							11
23.5–24.5			1	1					1		1								4
24.5–25.5		1																	1
25.5–26.5					1														1
26.5–27.5					1														1
27.5–28.5																			0
28.5–29.5																			0
29.5–30.5					1														1
	50	107	160	149	118	88	69	27	16	10	16	4	2	4	1	2	0	2	825

FIG. 44.—*Average weight of kernels per culm in milligrams, subject*
Total yield of culm in grams, relative. 1908
Coefficient of correlation = .464 ± .018

of grain, but not to so great an extent on those plants whose total yield alone is high.

The correlation between average weight of kernels per plant and total number of kernels per plant (Figs. 48, 49, 50), determined for three years, varies from —.253±.032 for 1910 to .071±.034 for 1912; while that between average weight of kernels per plant and average number of kernels per culm per plant (Figs. 51, 52, 53, 54), determined for

	.1–.2	.2–.3	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	
8.5–9.5	1			1															2
9.5–10.5				1															1
10.5–11.5	1				1														2
11.5–12.5					1		1				1								3
12.5–13.5					1	1				1									3
13.5–14.5		1		3	2	1	6	2	1		1	1							18
14.5–15.5		1	3	2	9	8	11	16	14	13	6	5	3	2					93
15.5–16.5	1		3	5	12	15	17	19	21	21	19	19	12	10	5	2	3	1	185
16.5–17.5		1		3	6	5	17	12	22	14	18	13	13	8	3	2	1		138
17.5–18.5			1	1	1	2	4	3	6	6	5	1	2	5		1			38
18.5–19.5								1	1	3	5			2	2		2		16
19.5–20.5																	1		1
	3	3	7	16	33	32	56	53	65	58	55	39	30	27	10	5	7	1	500

FIG. 45.—*Average weight of kernels per plant in milligrams, subject Average yield of culm per plant in grams, relative. 1909 Coefficient of correlation = .337 ± .027*

	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	
11.5–12.5						1											1
12.5–13.5	1	1	1			1											4
13.5–14.5	2		4		3	3	1	2	1								16
14.5–15.5		1	2	5	8	3	7	13	4	4	1	2					50
15.5–16.5		3	3	5	8	15	12	9	8	6	2	1					72
16.5–17.5	1	1	4	7	11	15	24	13	6	10	10	1					103
17.5–18.5		1	3	5	7	17	11	11	13	7	4	2	2				83
18.5–19.5				3	2	3	7	4	9	5	3	1					37
19.5–20.5			1	1	1	1	2	3	6	2		1				1	19
20.5–21.5				1		1	1	5	1	1							10
21.5–22.5				1	1	1		1									4
22.5–23.5																	0
23.5–24.5									1								1
	4	7	18	28	41	61	65	61	49	35	20	8	2	0	0	1	400

FIG. 46.— *Average weight of kernels per plant in milligrams, subject Average yield of culm per plant in grams, relative. 1910 Coefficient of correlation = .225 ± .032*

	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	1.9–2.0	
11.5–12.5				1	1	1	1		1							5
12.5–13.5		1	1	5	10	11	11	9	3	3						54
13.5–14.5		2	3	10	9	8	28	43	24	19	8	4				158
14.5–15.5	1	1	2	4	4	5	18	28	22	17	12	10	3	1		128
15.5–16.5				1			6	4	4	9	7	7	3		1	42
16.5–17.5							1	1				3	2		1	8
17.5–18.5										2		1				3
18.5–19.5								1	1							2
	1	4	6	21	24	25	65	86	55	50	27	25	8	1	2	400

FIG. 47.—*Average weight of kernels per plant in milligrams, subject Average yield of culm per plant in grams, relative. 1912 Coefficient of correlation = .429 ± .028*

	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550	550–600	600–650	650–700	700–750	750–800	
8.5–9.5	1			1													2
9.5–10.5			1														1
10.5–11.5	1			1													2
11.5–12.5			1		1					1							3
12.5–13.5				2			1										3
13.5–14.5	1	1	5	3	2	3	2		1								18
14.5–15.5	2	5	17	18	12	11	10	3	8	1	4	1		1			93
15.5–16.5	7	15	18	35	25	19	16	14	16	10	5	1	1	2	1		185
16.5–17.5	5	11	18	18	26	17	18	9	4	5	4		1		1	1	138
17.5–18.5	3	2	6	4	9	8	2	2	1						1		38
18.5–19.5		1	2	5	5			2				1					16
19.5–20.5				1													1
	20	35	68	88	80	58	49	30	30	17	13	3	2	3	3	1	500

FIG. 48.—*Average weight of kernels per plant in milligrams, subject Total number of kernels per plant, relative. 1909 Coefficient of correlation = .033 ± .030*

	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	
11.5–12.5			1								1
12.5–13.5		1	2			1					4
13.5–14.5	1	1	1	5	1	4	1	1	1		16
14.5–15.5		2	7	9	6	15	7	2	1	1	50
15.5–16.5		2	16	12	20	11	7	3	1		72
16.5–17.5		5	22	24	25	11	14	1	1		103
17.5–18.5	1	7	21	22	20	9	3				83
18.5–19.5		1	12	11	5	6	1			1	37
19.5–20.5		2	6	6	3	1		1			19
20.5–21.5			4	5	1						10
21.5–22.5			3	1							4
22.5–23.5											0
23.5–24.5				1							1
	2	21	95	96	81	58	33	8	4	2	400

FIG. 49.—*Average weight of kernels per plant in milligrams, subject Total number of kernels per plant, relative. 1910 Coefficient of correlation = −.253 ± .032*

	100–150	150–200	200–250	250–300	300–350	350–400	400–450	450–500	500–550	550–600	600–650	650–700	700–750	750–800	800–850	850–900	900–950	950–1000	1000–1050	1050–1100	1100–1150	1150–1200	1200–1250	1250–1300	
11.5–12.5						1	2	1										1							5
12.5–13.5		2	2	7	7	3	2	3	5	5	7	3	3	2	1	1		1							54
13.5–14.5	1	11	4	3	13	6	15	20	10	15	10	12	8	6	11	4	2	5		1	1				158
14.5–15.5	2	3	6	6	8	7	11	12	13	7	9	11	4	6	5	4	6	4			2		1	1	128
15.5–16.5		1	1		1	5	8	4	6	4	1		4		3	2						1		1	42
16.5–17.5						1	1			1	2	1									1	1			8
17.5–18.5					1	1			1																3
18.5–19.5					1		1																		2
	3	17	13	16	31	24	40	40	35	32	29	27	19	14	20	11	8	11	0	1	4	2	1	2	400

FIG. 50.—*Average weight of kernels per plant in milligrams, subject*
Total number of kernels per plant, relative. 1912
Coefficient of correlation = .071 ± .034

four years, varies from —.172 ± .033 for 1910 to .300 ± .021 for 1908. These correlations fluctuate strongly from year to year, and are never very high, although in some years the coefficients are large enough to be of considerable importance, especially when the coefficient is several times its probable error. From this it must be concluded that the relation of average weight of kernels to average and total number of kernels is responsive to environment, and varies independently much of the time. The kernels may increase in size or the number may increase without a corresponding change taking place in the other character.

	1–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
3.5– 4.5	2										2
4.5– 5.5	2										2
5.5– 6.5											0
6.5– 7.5	1				1						2
7.5– 8.5	1	1									2
8.5– 9.5	2										2
9.5–10.5	4					1					5
10.5–11.5		4	1		1	1					7
11.5–12.5	7	1	1								9
12.5–13.5	11	5									16
13.5–14.5	11	24	3								38
14.5–15.5	24	36	26	4	3						93
15.5–16.5	9	55	42	16	5			1			128
16.5–17.5	9	50	57	32	7	2	4		1		162
17.5–18.5	8	39	44	30	8	5	2	1		1	138
18.5–19.5	4	24	37	25	8	3		3	2	1	107
19.5–20.5	6	15	15	16	4	2	1				59
20.5–21.5	1	4	5	4	4	3					21
21.5–22.5	1	5	3		3	1					13
22.5–23.5	1	1	4	4	1						11
23.5–24.5	1	1		1	1						4
24.5–25.5	1										1
25.5–26.5		1									1
26.5–27.5		1									1
27.5–28.5											0
28.5–29.5											0
29.5–30.5		1									1
	106	268	238	132	46	18	7	5	3	2	825

FIG. 51.— *Average weight of kernels per culm in milligrams, subject*
Total number of kernels per culm, relative. 1908
Coefficient of correlation = .300 ± .021

The correlation between average weight of kernels per plant and average number of spikelets per culm per plant (Figs. 55, 56, 57), determined for

	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	100–110	110–120	
8.5– 9.5		1		1								2
9.5–10.5				1								1
10.5–11 5	1			1								2
11 5–12 5				1	1				1			3
12.5–13.5				2			1					3
13.5–14.5	1	1	3	2	6	3		2				18
14.5–15.5	1	5	10	14	22	21	11	7	2			93
15 5–16.5	1	6	18	30	33	31	30	22	8	5	1	185
16 5–17.5	1	3	10	25	31	25	26	11	4	2		138
17.5–18.5	1	2	3	8	9	6	5	3	1			38
18.5–19.5				2	6	2	3	2	1			16
19.5–20.5								1				1
	6	18	44	87	108	88	76	48	17	7	1	500

FIG. 52.—*Average weight of kernels per plant in milligrams, subject*
Average number of kernels per culm per plant, relative. *1909*
Coefficient of correlation = *.121 ± .030*

	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
11.5–12.5						1			1
12.5–13.5	1	1	1		1				4
13.5–14.5	2		4	4	3	3			16
14.5–15.5		4	8	8	14	10	4	2	50
15.5–16.5	2	5	14	21	15	11	4		72
16.5–17.5	3	9	21	36	13	15	6		103
17.5–18.5	3	7	26	18	19	7	3		83
18.5–19.5		3	10	11	10	3			37
19 5–20.5	1	2	3	10	1	1		1	19
20.5–21.5		1	6	2	1				10
21.5–22.5	1	1	2						4
22.5–23.5									0
23.5–24.5			1						1
	13	33	96	110	77	51	17	3	400

FIG. 53.—*Average weight of kernels per plant in milligrams, subject*
Average number of kernels per culm per plant, relative. *1910*
Coefficient of correlation = *—.172 ± .033*

	30–40	40–50	50–60	60–70	70–80	80–90	90–100	100–110	110–120	120–130	
11.5–12.5					1	2	1	1			5
12 5–13 5		1	1	12	7	18	10	4	1		54
13.5–14.5		2	9	13	18	45	46	18	5	2	158
14.5–15.5	1	1	5	7	22	40	27	19	5	1	128
15.5–16.5			1	2	6	10	10	10	2	1	42
16.5–17.5				1		1	3	2	1		8
17.5–18.5					2	1					3
18 5–19.5				2							2
	1	4	16	37	56	117	97	54	14	4	400

FIG. 54.—*Average weight of kernels per plant in milligrams, subject Average number of kernels per culm per plant, relative. 1912 Coefficient of correlation = .087 ± .033*

	1–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	
3.5– 4.5	2										2
4.5– 5.5	2										2
5.5– 6.5											0
6.5– 7.5	1				1						2
7.5– 8.5		1	1								2
8.5– 9.5		2									2
9.5–10.5	2	2					1				5
10.5–11 5		2	1	2	1	1					7
11.5–12.5	3	4	2								9
12.5–13.5	4	8	3	1							16
13.5–14.5	4	21	13								38
14.5–15 5	5	33	33	15	4	3					93
15.5–16.5	2	32	50	25	16	1	2				128
16.5–17.5	3	26	38	45	37	7	4	2			162
17.5–18.5	2	26	29	36	26	12	3	2	1	1	138
18.5–19.5		15	21	34	15	15	2	3	2		107
19.5–20.5	2	7	12	18	10	9	1				59
20.5–21.5		2	3	3	7	5	1				21
21.5–22.5		1	4	4	3	1					13
22.5–23.5		1	3	4	2	1					11
23.5–24.5		2			1	1					4
24.5–25.5	1										1
25.5–26.5			1								1
26.5–27.5			1								1
27.5–28.5											0
28.5–29.5											0
29.5–30.5		1									1
	33	186	215	187	123	56	14	7	3	1	825

FIG. 55.—*Average weight of kernels per culm in milligrams, subject Average number of spikelets per culm, relative. 1908 Coefficient of correlation = .329 ± .021*

	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	
8.5– 9.5		1		1						2
9.5–10.5				1						1
10.5–11.5		1			1					2
11.5–12.5				1	1			1		3
12.5–13 5			1	1			1			3
13.5–14.5	1	2	3	2	5	4	1			18
14 5–15 5	2	5	9	23	26	20	7	1		93
15.5–16.5	3	8	22	38	34	39	24	14	3	185
16 5–17.5	2	8	16	26	33	26	20	7		138
17.5–18.5		3	6	4	10	9	5	1		38
18.5–19.5				3	5	3	3	2		16
19.5–20.5						1				1
	8	28	57	100	115	102	61	26	3	500

FIG. 56.— *Average weight of kernels per plant in milligrams, subject*
Average number of spikelets per culm per plant, relative. 1909
Coefficient of correlation = .120 ± .030

	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	
11.5–12.5								1	1
12.5–13.5		1	2		1				4
13.5–14.5	2	1	1	2	5	5			16
14.5–15.5	1	2	3	10	15	11	5	3	50
15.5–16.5	1	4	11	19	17	11	8	1	72
16.5–17.5	3	5	13	28	28	17	7	2	103
17.5–18.5	2	1	22	17	21	13	7		83
18.5–19.5		3	3	10	13	7	1		37
19.5–20.5		2	1	5	8	2		1	19
20.5–21.5		1	2	5	2				10
21.5–22.5		1	1	1	1				4
22.5–23.5									0
23.5–24.5					1				1
	9	21	59	97	112	66	28	8	400

FIG. 57.— *Average weight of kernels per plant in milligrams, subject*
Average number of spikelets per culm per plant, relative. 1910
Coefficient of correlation = —.099 ± .033

three years, varies from —.099±.033 for 1910 to .329±.021 for 1908. This is a fluctuating correlation which is not high enough to be of importance, with the exception of that for 1908. This indicates that neither the large nor the small kernels tend strongly to be produced on those plants whose average culm yield is large or small.

The correlation between average weight of kernels per plant and average number of kernels per spikelet per plant (Figs. 58, 59), determined for

	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	1.9–2.0	2.0–2.1	2.1–2.2	2.2–2.3	2.3–2.4	2.4–2.5	2.5–2.6	2.6–2.7	
8.5– 9.5							1		1												2
9.5–10.5											1										1
10.5–11.5	1							1													2
11.5–12.5									1				2								3
12.5–13.5									1			2									3
13.5–14.5								1	3	6	3	1	2	2							18
14.5–15.5							4	4	9	12	16	17	16	12	1				1	1	93
15.5–16.5	1				1	2	3	9	13	24	24	40	38	18	8	3			1		185
16.5–17.5					1		4	7	2	19	24	31	29	10	5	2	2	1		1	138
17.5–18.5					1	1	1	1	1	7	8	12	2	2	1		1				38
18.5–19.5									1	6	3	2	2		2						16
19.5–20.5																		1			1
	2	0	0	0	3	3	13	23	32	74	79	105	91	44	17	5	3	2	2	2	500

FIG. 58.— *Average weight of kernels per plant in milligrams, subject*
Average number of kernels per spikelet per plant, relative. 1909
Coefficient of correlation = .120 ± .030

	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	1.9–2.0	
11.5–12.5					1							1
12.5–13.5			1		1			1	1			4
13.5–14.5				1	6	2	1	2	3	1		16
14.5–15.5			1	1	2	6	10	13	11	3	3	50
15.5–16.5			1	2	4	12	14	26	9	3	1	72
16.5–17.5	1		1	4	11	15	22	24	22	2	1	103
17.5–18.5		1	2	5	12	12	21	18	8	3	1	83
18.5–19.5				1	7	5	14	3	4	3		37
19.5–20.5		1			3	4	5	6				19
20.5–21.5					2	2	5	1				10
21.5–22.5			2	2								4
22.5–23.5												0
23.5–24.5				1								1
	1	2	8	17	49	58	92	94	58	15	6	400

FIG. 59.— *Average weight of kernels per plant in milligrams, subject Average number of kernels per spikelet per plant, relative. 1910 Coefficient of correlation = —.190 ± .033*

only two years, varies from —.190±.033 for 1910 to .120±.030 for 1909. These coefficients are not large enough to be of importance in either case, and indicate that the large and the small kernels appear about equally in spikelets containing many or few kernels.

The correlation between average weight of kernels per plant and number of culms per plant (Figs. 60, 61, 62), determined for three years, varies

	1	2	3	4	5	6	7	8	9	10	11	
8.5– 9.5		1		1								2
9.5–10.5		1										1
10.5–11.5	1			1								2
11.5–12.5			1	1	1							3
12.5–13.5				3								3
13.5–14.5		3	4	7	3		1					18
14.5–15.5		9	23	31	18	4	5	3				93
15.5–16.5	5	14	39	80	22	14	7	4				185
16.5–17.5	5	14	32	54	17	11	3		1		1	138
17.5–18.5	1	6	8	16	3	1	2		1			38
18.5–19.5	1	1	8	4		1	1					16
19.5–20.5		1										1
	13	50	115	198	64	31	19	7	2	0	1	500

FIG. 60.— *Average weight of kernels per plant in milligrams, subject Number of culms per plant, relative. 1909 Coefficient of correlation = —.021 ± .030*

	2	3	4	5	6	7	
11.5–12 5	1						1
12 5–13.5		2	2				4
13 5–14.5	2	2	9	2	1		16
14.5–15 5	4	12	25	9			50
15.5–16 5	7	22	29	11	3		72
16.5–17.5	12	33	47	6	4	1	103
17.5–18 5	14	34	28	6	1		83
18.5–19 5	5	14	16	1	1		37
19.5–20 5	5	9	3	2			19
20.5–21.5		5	5				10
21.5–22.5		1	2	1			4
22.5–23.5							0
23.5–24.5			1				1
	50	134	167	38	10	1	400

FIG. 61.—*Average weight of kernels per plant in milligrams, subject Number of culms per plant, relative. 1910 Coefficient of correlation = .184 ± .033*

	2	3	4	5	6	7	8	9	10	11	12	13	14	
11.5–12.5				4				1						5
12 5–13.5		3	16	4	7	13	10	1						54
13.5–14.5	2	11	20	35	23	24	30	7	4	1			1	158
14 5–15.5	2	9	17	19	21	17	25	11	4	1	2			128
15 5–16 5		2	6	13	6	6	5	2		2				42
16.5–17.5			1	1	2	1		1	1	1				8
17.5–18.5			1	1	1									3
18.5–19.5				1	1									2
	4	25	61	78	61	61	70	23	9	5	2	0	1	400

FIG. 62.—*Average weight of kernels per plant in milligrams, subject Number of culms per plant, relative. 1912 Coefficient of correlation = .050 ± .034*

from —.021±.030 for 1909 to .184±.033 for 1910. This again is fluctuating and weak, which signifies that both large and small kernels are found on plants that produce few or many culms.

Considering the relation of average weight of kernels per plant to other plant characters as a whole, it is evident that kernel weight is not correlated closely and consistently with any other character here considered. The highest and most stable correlation found is that with average yield of culm per plant, in which the correlation is always positive and rather

	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	1.9–2.0	2.0–2.1	2.1–2.2	2.2–2.3	2.3–2.4	2.4–2.5	2.5–2.6	2.6–2.7	
10–15	1							2		1	2					1				1	8
15–20	1				2		2	6	2	5	1	4	1	2			1	1			28
20–25						1	4	2	8	15	9	7	6	2			2		1		57
25–30					1	1	4	5	12	16	17	21	12	6	4	1					100
30–35						1		4	5	23	23	22	26	8	2					1	115
35–40							3	2	4	11	17	23	23	15	2	1		1			102
40–45								2	1	2	6	23	14	6	6				1		61
45–50										1	4	5	9	3	2	2					26
50–55														2	1						3
	2	0	0	0	3	3	13	23	32	74	79	105	91	44	17	5	3	2	2	2	500

FIG. 63.— *Average number of spikelets per culm per plant, subject*
Average number of kernels per spikelet per plant, relative. *1909*
Coefficient of correlation $= .324 \pm .027$

high. In all other cases, however, the correlation varies in the different years from a negative correlation, sometimes of appreciable value, to a comparatively high positive correlation. It is evident, therefore (1) that average weight of kernels in oats has no necessary dependent relation to yield, total and average number of kernels, average number of spikelets and of kernels per spikelet, and number of culms, and (2) that the relation which does exist is largely responsive to environment. It seems that when development is arrested by environmental conditions, yield is reduced by reduction in number of kernels per plant, per culm, and per spikelet, rather than in average weight of kernels and in number of spikelets produced.

Correlation of average number of spikelets per culm per plant with other characters

The correlation between average number of spikelets per culm per plant and average number of kernels per spikelet per plant (Figs. 63, 64), deter-

	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	1.9–2.0	
15–20		1		1	3	2		1	1			9
20–25			2	1	6	5	6		1			21
25–30			4	1	8	10	16	11	7	1	1	59
30–35		1	1	6	12	19	25	14	14	2	3	97
35–40			1	4	9	15	30	33	12	6	2	112
40–45	1			2	10	4	10	20	16	3		66
45–50				2		2	5	11	6	2		28
50–55					1	1		4	1	1		8
	1	2	8	17	49	58	92	94	58	15	6	400

FIG. 64.— *Average number of spikelets per culm per plant, subject*
Average number of kernels per spikelet per plant, relative. *1910*
Coefficient of correlation $= .253 \pm .032$

mined for two years, varies from $.253 \pm .032$ for 1910 to $.324 \pm .027$ for 1909. This is rather high and fairly constant. From this it may be concluded that there is considerable relation between the number of spikelets produced and the number of kernels produced in these spikelets, an increase in one being associated with an increase in the other.

The correlation between average number of spikelets per culm per plant and number of kernels per culm (Fig. 65) was determined for only one

	1–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
1–5	33										33
5–10	63	123									186
10–15	7	120	87	1							215
15–20	2	17	132	36							187
20–25	1	7	18	78	14	5					123
25–30		1	·1	17	29	6	1	1			56
30–35					3	6	4	1			14
35–40						1	2	1	3		7
40–45								2		1	3
45–50										1	1
	106	268	238	132	46	18	7	5	3	2	825

FIG. 65.— *Number of spikelets per culm, subject*
Total number of kernels per culm, relative. *1908*
Coefficient of correlation = *.880* ± *.005*

year, 1908, when it was .880±.005. This indicates a very high correlation between these two characters, from which it may be concluded that the spikelet and kernel development of the plant are mutually related.

Considering as a whole the relation of the average number of spikelets per culm per plant with other characters, it has been seen that as the spikelets increase or decrease there is likewise a strong, simultaneous increase or decrease in the number of kernels produced, and a fairly strong similar change in number of kernels per spikelet.

Correlation of number of culms per plant with other characters

The correlation between number of culms per plant and average yield of culm per plant (Figs. 66, 67, 68), determined for three years, varies

	.1–.2	.2–.3	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	
1	1			1	1	3	3	3									1		13
2	2	3	3	5	8	3	7	5	5	4	2		1	1			1		50
3				5	14	11	16	20	12	14	12	5		4	2				115
4			3	5	10	12	22	17	29	27	22	18	11	10	5	3	3	1	198
5			1			3	5	4	12	6	7	7	10	5	3	1			64
6							3		2		8	8	5	3		1	1		31
7								2	4	6	2	1	1	2			1		19
8								1	1	1	1		2	1					7
9								1						1					2
10																			0
11											1								1
	3	3	7	16	33	32	56	53	65	58	55	39	30	27	10	5	7	1	500

FIG. 66.— *Number of culms per plant, subject*
Average yield of culm per plant in grams, relative. *1909*
Coefficent of correlation = *.387.* ± *.026*

	.3–.4	.4–.5	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	
2	1	2	5	1	5	6	11	6	5	4	2	1	1				50
3		3	8	11	20	25	18	16	18	7	4	3	1				134
4	2	1	5	10	11	24	29	31	17	21	13	2				1	167
5		1		4	3	6	5	7	7	3	1	1					38
6				2	2		2	1	2			1					10
7	1																1
	4	7	18	28	41	61	65	61	49	35	20	8	2	0	0	1	400

FIG. 67.—*Number of culms per plant, subject*
Average yield of culm per plant in grams, relative. 1910
Coefficient of correlation $= .070 \pm .034$

	.5–.6	.6–.7	.7–.8	.8–.9	.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6	1.6–1.7	1.7–1.8	1.8–1.9	1.9–2.0	
2				2				2								4
3			4	9	1	3	3	1	2	1		1				25
4	1	3	1	4	7	8	11	10	2	5	5	3	1			61
5		1	1	2	6	1	13	20	13	12	5	3	1			78
6				1	5	4	12	13	11	7	4	2	1	1		61
7				1	3	6	14	13	12	5	2	4			1	61
8				2	2	3	9	20	9	12	5	7	1			70
9							1	5	3	7	5	2				23
10							1		3	1	1	1	1		1	9
11								1				1	3			5
12								1				1				2
13																0
14							1									1
	1	4	6	21	24	25	65	86	55	50	27	25	8	1	2	400

FIG. 68.—*Number of culms per plant, subject*
Average yield of culm per plant in grams, relative. 1912
Coefficient of correlation $= .383 \pm .029$

from $.070 \pm .034$ for 1910 to $.387 \pm .026$ for 1909. This is a fluctuating correlation which is only fairly high in any case. From this it may be concluded that the relation between culm production in the plant and the yield of the separate culms is not very close, and is also subject to modification by varying environmental conditions. It was seen above, however, that the relation of number of culms to total yield of plant is very

high, from which it is clear that the separate culms of a plant vary considerably among themselves, thereby reducing the correlation when the average culm yield is considered.

The correlation between number of culms per plant and average number of kernels per culm per plant (Figs. 69, 70, 71), determined for three years, varies from .132±.033 for 1910 to .423±.025 for 1909. This again is a fluctuating correlation, not particularly high in any case. It indicates that the relation between the number of culms produced and the number

	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	100–110	110–120	
1	1	1	2	7	1				1			13
2	5	7	9	12	6	8	2	1				50
3		4	18	24	35	19	11	4				115
4		5	15	36	43	38	25	23	9	3	1	198
5		1		4	15	14	13	10	6	1		64
6				2	4	1	15	7		2		31
7				1	3	7	6		1	1		19
8					1	1	2	3				7
9				1			1					2.
10												0
11							1					1
	6	18	44	87	108	88	76	48	17	7	1	500

FIG. 69.—*Number of culms per plant, subject*
Average number of kernels per culm per plant, relative. 1909
Coefficient of correlation = .423 ± .025

	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	
2	5	3	10	16	9	4	3		50
3	2	17	42	38	25	8	1	1	134
4	4	10	33	43	35	30	11	1	167
5	1	2	8	11	7	6	2	1	38
6		1	3	2	1	3			10
7	1								1
	13	33	96	110	77	51	17	3	400

FIG. 70.—*Number of culms per plant, subject*
Average number of kernels per culm per plant, relative. 1910
Coefficient of correlation = .132 ± .033

	30–40	40–50	50–60	60–70	70–80	80–90	90–100	100–110	110–120	120–130	
2			1	1	1	1					4
3			11	4	4	2	2	2			25
4	1	3	1	12	12	16	9	6	1		61
5		1	2	6	10	26	23	10			78
6			1	6	12	16	19	5	1	1	61
7				3	9	26	15	5	2	1	61
8				4	7	21	18	13	5	2	70
9				1		5	8	9			23
10						2	3	1	3		9
11						1		2	2		5
12						1		1			2
13											0
14					1						1
	1	4	16	37	56	117	97	54	14	4	400

FIG. 71.—*Number of culms per plant, subject*
Average number of kernels per culm per plant, relative. 1912
Coefficient of correlation = .408 ± .028

of kernels per culm may on occasion be high, but is modified by environmental conditions.

Considered as a whole, the relation of number of culms per plant to the other plant characters dealt with has been shown to be fluctuating, generally to a considerable degree, being influenced by different environmental conditions. The correlation is not especially high in any case, except when total plant yield is considered. The conclusions may be drawn, then, (1) that when conditions are favorable, the number of culms will vary to a large extent directly with height of plant, average culm yield, and average number of kernels, but that this relation may, on occasion, entirely disappear; and (2) that the number of culms will vary directly and constantly with the total plant yield; but (3) that the number of culms and the average weight of kernels move practically independently of each other under all conditions.

Constants for 1910 compared with other years

The correlation coefficients for the year 1910 are worthy of special consideration. It is seen that with one exception the only negative coefficients found occur in this one year, five appearing in 1910. The coefficients for 1910 are also noticeably lower, as a general rule, than those of the other years. Of the twenty-two cases involved, there are sixteen that are lower than those of the correlation coefficients determined

between the same characters in different years, while only one is higher than all others, and five are intermediate. This condition in 1910 seems to be due to the influence of undetermined environmental conditions on the development of the plants and their seeds. As stated earlier in this paper, this crop was grown on a different, less fertile, soil than were the crops for the other years. This, together with the climatic conditions of 1910, no doubt had the most to do with affecting the correlation coefficients.

By comparing the coefficients of correlation, however, for the years 1908 and 1910, it is seen that those for 1908 are never much lower, but frequently are considerably higher, than those for 1910. The coefficients for 1908 are generally high in comparison with those of all the other years. Those for 1910, on the other hand, were low in comparison, as stated above. It seems, therefore, that in both 1908 and 1910 there were conditions operating which prevented maximum vegetative development and reduced the yield, in the manner stated above; but that these conditions had a different effect on the correlations, increasing, or failing to reduce markedly, those for 1908, and generally decreasing those for 1910. Such results would be expected if in 1908 the plants were grown on poor soil or were crowded but were subject to good weather conditions, and if in 1910 the plants were grown on more fertile soil or in less crowded conditions but at a critical time in the development of the kernels adverse weather conditions prevailed. The former premise would be in agreement with the results of Myers (1912), who found, when working with wheat, that correlations are higher in plants grown on poorer soil, weather conditions being the same. It has been shown above that the culms used in 1908 were from plants grown in drill rows, thus agreeing with the supposed conditions. In 1910 also, as shown above, the plants were given more room than in 1908, but the same room as in other years, while the weather conditions were not favorable.

DISCUSSION OF RESULTS

The means indicate that the growing conditions were not so favorable for the 1910 crop as for those of 1909 and 1912, and resulted in smaller plants and a reduced total yield of grain; but that these smaller plants produced a larger number of spikelets (compared with 1909 only) and larger kernels. The plants of the 1908 crop were grown in drill rows, in

more crowded conditions than were those of other years, with the result that the culms were not so tall and the number of spikelets, number of kernels, and yield were all less, but the kernels were practically as large as, or larger than, in any other year except 1910.

It seems that when development is arrested by environmental conditions, yield is reduced by a reduction in number of kernels per plant, per culm, and per spikelet, rather than in average weight of kernels and in number of spikelets produced.

Coupled with the less plant development and yield of 1908 and 1910, there is less variability, as indicated by the standard deviation, in number of culms, total and average number of kernels, total yield, average number of spikelets, and average number of kernels per spikelet. In average weight of kernels, however, there is greater variability in 1908 and 1910.

The relation of these correlation factors to oat production

The value of correlation in breeding and development work has been pointed out from time to time. When certain characters are associated to a high degree, it is possible to so select plants as to increase one character and at the same time increase another because of this correlation.

The results of these studies are of importance in the breeding and production of oats. In the beginning of this paper the question was raised whether the tallest plants produce the most grain. Data have been presented to show that there is a high correlation between these characters so far as this pure line is concerned. This indicates that the growth factors influence the developing plants in such a way that tall plants and high yield of grain are found together.

If these correlations represent the truth, on the whole, for oats during the years represented, and if it were desired to save seed from a field, it would be more advantageous to save seed from the tallest plants; for in so doing one would naturally be selecting seed from the heaviest producers as well.

It is also interesting and important to note that as the plants tend to increase in height, the number of culms also increases. At the same time it is shown also that the average yield per culm increases as the height of plant increases. This shows the possibility of obtaining plants with many culms that may be high in production, which is rather important,

since it is sometimes thought that the average yield of culm would tend to decrease as the number of culms on the plant increased.

Another important fact brought out by this study is the relation between average weight of kernels and height of plant, and average weight of kernels and total yield. This has an important bearing on the practice of seeding oats.

The question of size of seed is one that has been much discussed. The common advice given to a grower is that he should reclean his seed in order to obtain only the largest and plumpest for sowing. Many experiments have been conducted in order to determine the relative value of light and heavy seed. Among these, and possibly the best known of all such experiments, are those under the direction of Professor C. A. Zavitz, at Guelph. In these experiments Professor Zavitz worked with hand-picked seed, thus being sure to have a good separation of light and heavy grains. The results show a good gain in yield per acre from the heavy seed. Other results with small grains have been obtained at the Ohio Agricultural Experiment Station (Williams and Welton, 1911 and 1913), and also at the Nebraska Agricultural Experiment Station (Montgomery, 1908). These results do not agree with those found by Professor Zavitz, since no marked results were obtained by sowing larger seed. The difference between the seed used by Professor Zavitz and that sown at the Ohio and Nebraska Stations was that the former was hand-picked and the latter was separated by the use of a fanning mill.

One of the writers has sown hand-picked seed of a number of varieties of oats, and found that in every case the larger yield was obtained from the heavy seed. In another test with oats, in which large and small kernels from the same head were compared, the large seed gave a greater yield.

Although there have been many experiments comparing large and small seed, few studies have been made to determine the parentage of the large seed. Do large seeds come from large plants, or do the smaller, low-yielding plants produce a large percentage of heavy seed? Another point along this line that needs consideration is the relative value of small seed from large plants, as compared with large seed from small plants.

Waldron has made a valuable contribution to the study of light and heavy seed. His data were taken on oats, but he also made some calculations on data taken by Dr. T. L. Lyon and reported in Bulletin 78 of the United States Bureau of Plant Industry. Waldron's paper shows the value of the

statistical method of analysis in dealing with such problems. He suggests the importance of a closer analysis of our plants in order to determine some of the fundamental truths that may serve as a basis for improvement. The results, especially with respect to oats, reported in this paper, cast some doubt on the wisdom of planting only the heaviest seed. The data as reported by Waldron show that the heaviest seed come from the smaller rather than from the larger plants. This immediately raises the question as to whether one can reasonably expect gains from the largest seed.

Waldron arranged his data in correlation tables, and determined the correlation between the following characters: average weight of seed and number of grains; average weight of seed and length of head; average weight of seed and length of culm. The calculations showed a negative correlation of -0.595 ± 0.013 between average weight of seed and number of grains; while for average weight of seed and length of head, and average weight of seed and length of culm, correlation coefficients of -0.511 ± 0.015 and -0.404 ± 0.017, respectively, were found. The constants show that the larger kernels are borne by short plants having short heads and producing only a small number of kernels per head; or, in other words, the smallest plants are the ones that produce the heaviest seed. From these data, then, it seems possible that in sowing the heaviest seed one is not using seed from the best-yielding plants.

Some results presented in this paper are of interest in this connection. These studies have to do with the relation between tall plants and average weight of seed; and heavy-yielding plants and average weight of seed. If there is a tendency for certain plants to produce large seed and at the same time be taller or higher-yielding than the average plants of a population, then when heavy seed is selected one would at the same time be selecting tall, high-yielding plants. If, on the other hand, there is no correlation between average weight of seed and height or yield, so that the large seeds are borne in equal amounts by tall and short plants and by heavy- and light-yielding plants, then when heavy seed is selected one is at the same time selecting mediocre plants or those tending to represent the average of the race. Under this condition one would not expect much increase in yield from large seed, while, if the other condition mentioned above holds, it would be natural to expect increase in yield from large seed.

When one compares the correlation coefficients for average height of plant and average weight of kernels for the years 1909, 1910, and 1912[5] — which are $.219 \pm .029$, $-.023 \pm .034$, and $.217 \pm .032$, respectively — some information is obtained concerning the question of light and heavy seed. For the two years 1909 and 1912 the coefficients are practically the same, while for 1910 the coefficient is negative and at the same time it is so low that it shows no relation between these characters for this year. These coefficients show that to some extent the taller plants tend to produce kernels of larger average size for two years, while for the other year this condition does not hold. If these facts represent the average condition for oats for the years 1909 and 1912, were one to select large seed from these crops for planting he would also be selecting plants that are taller. These might have a tendency to produce heavier-yielding plants the next year. On the other hand, if seed were selected from the 1910 crop, tall and short plants would be selected in equal numbers, and the tendency on the whole would be for the plants of the succeeding crop to represent the average conditions rather than to be larger because of the large seed planted.

The correlation coefficients for yield per plant and average weight of kernels for the same three years are $.149 \pm .029$, $.035 \pm .034$, and $.220 \pm .032$, which are very similar to those for average height of plant and average weight of kernels. For the year 1910 there is no relation as measured by the coefficient of correlation between the two characters in question, while there is some relation between these characters for 1909 and 1912, and, provided these facts are true for oats in general for those years, by selecting larger seed one would be obtaining these from the higher-yielding plants. On the other hand, when one selects seed from the 1910 crop, plants having a tendency to yield high or low may be obtained in equal amounts.

Another correlation which is of importance in a practical way is that between average height of plant and average number of spikelets per culm per plant. This correlation for the two years is very high, which shows that it is entirely possible to have tall plants which at the same time will have a high average number of spikelets per culm. This is important, since there is a good correlation between average number of spikelets per culm and average number of kernels per spikelet. Taking both these

[5] 1908 is omitted, since this represents average weight of kernels per culm rather than per plant.

correlations into consideration, it is seen that yield may be increased by selecting the taller plants, which will at the same time have a high average number of spikelets per plant associated with a high average number of kernels per spikelet.

These correlations indicate that it is possible to use certain vegetative characters as a basis for selection when improvement work is to be considered. If from a mixed population tall plants, with a high average number of spikelets per head and with these spikelets well filled with kernels, are selected, one will be selecting plants that will on the whole be high in production.

More evidence is also given in regard to the question of light and heavy seed. The results seem to indicate that for certain years it may be reasonable to expect heavy seed to give a large yield, while for other years the reverse may be the case.

SUMMARY

From the data herein presented the following conclusions may be drawn:

1. Environmental conditions such as exist in different years cause changes in the means. Conditions that generally result in reduction of plant yield also result in reduction of height, number of kernels, and number of culms, but in increase in size of kernels.

2. Yield is reduced by decrease in number of kernels produced, rather than by decrease in their size.

3. Variability decreases with decrease in the means.

4. Correlations are more or less responsive to environmental conditions, and may be divided into *fluctuating* and *stable*, according to their behavior under differing environments.

5. There are high, positive, and fairly stable correlations between average height of plant and (a) total and average yield, (b) total and average number of kernels produced, (c) average number of spikelets per culm; the correlations between average height of plant and (d) average weight of kernels, (e) number of culms, are fluctuating, being high or low on occasion.

6. There are high, positive, and stable correlations between total yield and (a) culm yield, (b) total and average kernel production, (c) spikelet production, (d) culm production.

7. The average kernel weight is not correlated closely and consistently with any other character here considered, except average culm yield, with which the correlation is fairly high and fairly consistent.

8. The average number of spikelets per culm per plant is correlated (a) fairly highly with the average number of kernels per spikelet; (b) apparently very highly with number of kernels per culm; (c) very highly and stably with average height of plant and total yield; and (d) in a fluctuating manner with kernel weight.

9. The correlations between number of culms per plant and (a) height, (b) culm yield, (c) number of kernels, are fluctuating, varying greatly from high to low; between number of culms per plant and (d) total yield they are high, positive, and stable; between number of culms per plant and (e) average kernel weight they are fairly stable and always low.

LITERATURE CITED

Leighty, C. E.
1912 Correlation of characters in oats, with special reference to breeding. Amer. Breeders' Assoc. Ann. rept. **7**(1911):50–61.

Love, H. H.
1912 A study of the large and small grain question. Amer. Breeders' Assoc. Ann. rept. **7**(1911):109–118.

Montgomery, E. G.
1908 Cultivation of small grains. The use of the fanning mill for selecting seed wheat and seed oats. Nebraska Agr. Exp. Sta. Bul. 104:1–34.

Myers, C. H.
1912 Effect of fertility upon variation and correlation in wheat. Amer. Breeders' Assoc. Ann. rept. **7**(1911):61–74.

Roberts, H. F.
1912 Variation and correlation in wheat. Amer. Breeders' Assoc. Ann. rept. **7**(1911):80–109.

Waldron, L. R.
1910 A suggestion regarding heavy and light seed grain. Amer. nat. **44**:48–56.

Whitcomb, W. O.
1913 A study of statistical methods with barley. Amer. Soc. Agron. Journ. **5**:83–101.

Williams, C. G., and Welton, F. A.
1911 Wheat experiments. Ohio Agr. Exp. Sta. Bul. 231:1–22.
1913 Oats. Ohio Agr. Exp. Sta. Bul. 257:255–283.

Zavitz, C. A.
1909 The yields of plants as influenced by the size of the seeds used. Ontario Agr. Coll. and Exp. Farms. Ann. rept. **34**(1908): 180–181.
1910 The yields of plants as influenced by the size of the seeds used. Ontario Agr. Coll. and Exp. Farms. Ann. rept. **35**(1909): 179–180.
1912 Influence of seed selection. Ontario Agr. Coll. and Exp. Farms. Ann. rept. **37**(1911):181–183.

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VARIATION AND CORRELATION OF OATS (AVENA SATIVA)

PART II. EFFECT OF DIFFERENCES IN ENVIRONMENT, VARIETIES, AND METHODS ON BIOMETRICAL CONSTANTS

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CONTENTS

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PART II. EFFECT OF DIFFERENCES IN ENVIRONMENT, VARIETIES, AND METHODS ON BIOMETRICAL CONSTANTS[1]

CLYDE E. LEIGHTY[2]

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INTRODUCTION

Biometrical methods have recently come into considerable use in studies of genetics. An increasing number of papers discussing the subject are appearing each year, and work of this kind promises to be an important addition to the literature bearing on variation, correlation, and inheritance. The use of the exact methods of measurement required, and the possession of formulæ by means of which a mass of data may be concisely and accurately expressed, mark distinct advances in the science of genetics. It is difficult, for example, for the mind to grasp the data concerned in the relation of height and yield for a thousand plants, but if such data are expressed as a correlation coefficient in a single number the difficulty disappears.

With increasing use of these biometrical methods, a determination of their exact status in studies of variation, correlation, inheritance, and the like, is of importance. It is important to know the conditions that must exist to make comparable the results obtained, to know the effect of environment and hereditary differences on the constants determined. It is also of importance to know, and to have expressed in a statistical way, the variation and correlation that exist in and between the various important characters of many plants. This is especially true of plants of economic importance on which breeding work is being done.

The studies herein reported are on oats (*Avena sativa*), with which considerable breeding work is being done and which stand in need of a

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large amount of such work. Biometrical methods are used in this study, the various constants determined being the mean, the standard deviation, the coefficient of variability, the coefficient of correlation, and the probable error of each of these.

It is important to know these values for any plant for whose improvement breeding efforts are being made. Such statistical data should largely direct the efforts and add definiteness to the operations. The mean enables one to know what any strain or variety is likely to do, on the average, in its various characters. The standard deviation and the coefficient of variability are indices of variation: the former is perhaps the best index of variation that is in use for the same or like characters of different lots of material measured in the same units; the latter is of value when the variations of unlike characters of different lots of material measured in dissimilar units are compared.

Rietz and Smith (1910: 296)[3] define the correlation coefficient as follows: "The correlation coefficient may be defined as the mean product of deviations of corresponding variates from their mean values in units of the standard deviations." The correlation coefficient is of especial value in relation to selection. In the processes involved in selection for any one character, several other characters may at the same time be modified incidentally. By the modification of such characters the correlation in succeeding generations may be modified in inexplicable ways unless the correlations of the parents are known. Again, the actual work of selecting desirable plants is dependent on the correlations that exist in the plants themselves. For example, if the purpose of selection is to increase yield, the relation of this character to height is often of importance.

These studies are not exhaustive, nor could they well be made so. Certain correlations have been determined for several varieties of oats. No inheritance studies are here included. These results must therefore be considered as being preliminary to such studies, for it is of fundamental importance to know the correlations that exist between the different characters of the parental plants before definite and intelligent progress can be made in the study of inheritance, which is the correlation that exists between parents and offspring.

[3] Dates in parenthesis refer to "Literature cited," page 1077.

In addition to the study of the correlations as they exist in oats, other features have been introduced in order to determine the status of correlation studies, to find out how correlations may be modified, and to determine which correlations are capable of modification. These studies have gone hand in hand with studies of the mean and of variation.

The method used in determining the correlation coefficients herein reported is the short method given by Rietz and Smith (1910). The correlation tables and frequency distributions were made from the data taken on the plants, which had been copied on cards, one card containing all data for the culm or the plant dealt with. The cards for any series were then grouped according to the classes of the subject character, and each group was then divided according to the classes of the relative character. By counting the cards in the final groups and entering the numbers in the proper rectangle, correlation tables were made. All formulæ used are contained in Davenport's "Principles of Breeding" (1907).

CHARACTERS USED

The characters of oats dealt with in these studies are:

Height of culm and average height of plant

The height of culm was measured, in millimeters, from the root crown to the base of the apical spikelet. The average height of plant was determined by dividing the sum of the culm lengths by the number of culms possessed by the plant.

Average length of head per plant

This was obtained by dividing the sum of the head lengths of the plant by the number of culms per plant. The length of head was measured, in millimeters, for each culm, the head being considered as extending from the node marking its origin to the base of the apical spikelet.

Weight of plant

Total weight of plant.— This was obtained usually by weighing the entire plant, exclusive of the root, in centigrams. In some cases it was obtained by adding together the weights of the separate culms of the plant.

Total weight of culm.— This was obtained for a few series by weighing in centigrams, separately, the different culms making up the plant, using the entire culm, exclusive of the root. This is the same as the total weight of plant in cases of single-culmed plants.

Average weight of culm per plant.— This was obtained by dividing the total weight of plant, obtained as described above, by the number of culms per plant. The average weight of culms as herein used is often identical with the total weight of plant, this occurring when a single culm forms the plant.

Number of kernels

This was obtained by counting the number of kernels produced by the entire plant, or in some cases by each culm. The average number of kernels per culm was obtained by dividing the total number per plant by the number of culms of the plant.

Number of spikelets

This was obtained in the same way as was the number of kernels.

Number of kernels per spikelet of plant

This was obtained by dividing the number of kernels per plant by the number of spikelets per plant.

Weight of straw

Total weight of straw for the entire plant.— This was obtained by subtracting the total weight of kernels per plant from the total weight of plant.

Total weight of straw per culm.— This was obtained by subtracting the total weight of kernels per culm from the total weight of culm.

Average weight of straw per culm of plant.— This was obtained by dividing the total weight of straw per plant by the number of culms per plant.

Average weight of kernels per plant

This was obtained by dividing the total weight of kernels per plant by the number of kernels per plant.

Diameter of straw

This was obtained by measuring, in decimillimeters, by means of calipers, the greatest diameter of the second internode below the head of the most important culm of the plant.

Breaking strength of straw

This was determined for the internode measured above. The method employed was to cut a piece of straw to a length of eight centimeters, using the part nearest the root. This piece was then placed across an

auger hole in a board, the hole being 5.5 centimeters in diameter. A tiny bucket was then suspended from the middle point of the piece of straw by means of a hook made from wire about one millimeter in diameter. Shot was then poured into the bucket at a uniform rate until the straw broke. A very fine shot, about No. 12, was used. The combined weight of the bucket and the shot required in order to break the straw was considered as the breaking strength of the straw.

Yield

Total yield of plant.— This was determined by weighing, in milligrams, the grain produced by the plant, or by adding together the yields determined for individual culms of the plant.

Total yield of culm.— This was determined in some series by weighing the grain produced by each culm.

Average yield of culm per plant.— This was obtained by dividing the total yield of the plant by the number of culms per plant.

MATHEMATICAL METHODS

In determining the mathematical results herein reported, calculations were made to the fifth decimal place. If the fifth place exceeded five in value the fourth place was increased by one, otherwise the fifth number was dropped. With the exception of the coefficient of variability, the constants are reported with three decimal places, the fourth place, determined as above, being dealt with as was the fifth place above. When the constants reported in this paper were used in the determination of other constants, as the coefficient of variability, they were used as herein reported; that is, with three decimal places.

Rietz and Smith (1910 : 304), following Pearson, make the following statement regarding the significance of the probable errors:

"In the comparison of two statistical results, the difference between the two results compared to its probable error is of great value. In general, we may take the probable error in a difference to be the square root of the sum of the squares of the probable errors of the two results. If the difference does not exceed two or three times the probable error thus obtained, the difference may reasonably be attributed to random sampling. If the difference between the two results is as much as five to ten times the probable error, the probability of such differences in random sampling is so small that we are justified in saying that the differ-

ence is significant. In fact a difference of ten times its probable error is certainly significant in so far as there is certainty in human affairs."

This method of determining the error of the difference of statistical results compared has been used in the present paper.

STUDIES TAKEN UP

The following studies have been taken up and are separately considered hereinafter :

1. Comparison of biometrical constants determined for oat plants and for the culms of the same plants.
2. Biometrical comparison of varieties of oats.
3. Comparison of biometrical constants determined for oat plants grown in hills and in drills.
4. Effect of different degrees of crowding on biometrical constants of oats.

The correlation tables for each division are included in the text in proximity to the discussion of the constants determined for each table, except in cases when the same series enters into more than one division.

Comparison of biometrical constants determined for oat plants and for the culms of the same plants

In taking up variation and correlation studies with the cereals, the question arises as to whether the plants should be considered as units or whether the individual culms of the plants may be considered as the units with which to work. If plants are used as units, averages per culm of plant must be dealt with in many instances. If culms are the units, the actual culm measurements are dealt with directly. The feeling may often arise in such work that the measures of variation and correlation may differ somewhat, or even essentially, according to the method used.

Investigators have made use of one or the other method, or both, rather indiscriminately. Waldron (1910) has used culms as units in studies with oats, although practically every culm used by him was the entire plant, due to the conditions under which the oats were grown. Roberts (1911) dealt with culms of wheat as units for the crop of one year, and with plants as units for the crop of the succeeding year. Myers (1911) reported correlations for wheat, plants being used as the

units for correlation. The writer (1911) reported data on oats, plants being used as units; but in the same paper some constants worked out by Humbert were quoted, these having been worked out with the culm as the unit of calculation. Atkinson (1912), in some recent and as yet unpublished work, has used the culm as the unit in statistical work with several varieties of wheat.

It seemed important, therefore, in view of the considerable amount of statistical work being done with the cereals, to make some trial of these methods in order to determine their comparative value. Accordingly 300 plants of oats, grown in 1911, three inches apart in rows one foot apart, were chosen for use. These were a pure line (137–6) of the variety Early Champion, which had been grown for several years by the Department of Plant-Breeding at Cornell University. Each culm of each of these 300 plants was measured and recorded separately, the yield and the number of grains produced on each culm being a part of the data taken. There were in all 862 culms produced by the 300 plants, or an average of 2.87+ culms per plant. The numbers of plants, with the different numbers of culms, are as follows:

Number of culms per plant...	1	2	3	4	5	6	7	8
Number of plants............	41	52	144	39	18	4	1	1

The constants for the variation and correlation of certain characters of these plants were then determined, the various culms being dealt with as individuals in the one case and the plants being dealt with as individuals in the other; in the latter case, the average per culm of plant being determined. The means and measures of variation determined by the two methods are given in Table 1. Series 1221 is the series worked with, the individual plants here being the units. Series 22 is the designation given to the culms making up the plants of series 1221, when these separate culms are dealt with as units.

The data in Table 1 will now be considered. The average yield of culm per plant in decigrams has a mean of $7.890 \pm .118$. The total yield of culm in decigrams has a mean of $8.416 \pm .109$. The yield of culm is larger by $.526 \pm .161$ decigrams, the difference being only about three times its probable error. Considering standard deviation, it is seen that for the average yield of culm per plant it is $3.034 \pm .083$, while for the total yield of culm it is $4.728 \pm .077$. The coefficients of variability

are, respectively, 38.45 ± 1.20 and 56.18 ± 1.16. These figures express a considerably greater variability in the yield per culm than in average yield of culm per plant.

TABLE 1. SERIES 1221 AND 22 COMPARED. IN SERIES 1221 THE INDIVIDUAL PLANTS ARE DEALT WITH AS UNITS. IN SERIES 22 THE SEPARATE CULMS OF THE SAME PLANTS ARE DEALT WITH AS UNITS

Series 1221	Series 22
Average yield of culm per plant, in decigrams	Yield of culm, in decigrams
M $7.890 \pm .118$	M $8.416 \pm .109$
σ $3.034 \pm .083$	σ $4.728 \pm .077$
C 38.45 ± 1.20	C 56.18 ± 1.16
Average height of plant, in centimeters	Height of culm, in centimeters
M $58.683 \pm .290$	M $59.971 \pm .242$
σ 7.462 ± 205	σ 10.519 ± 170
C $12\ 72 \pm 36$	C $17\ 54 \pm .29$
Average number of kernels per culm of plant	Number of kernels per culm
M 55.293 ± 737	M $58\ 176 \pm .655$
σ $18.942 \pm .521$	σ 28.496 ± 462
C $34.26 \pm 1\ 05$	C 48.98 ± 97
Average number of spikelets per culm of plant	Number of spikelets per culm
M $31.427 \pm .393$	M 32.979 ± 338
σ $10.110 \pm .278$	σ $14.714 \pm .238$
C $32.17 \pm .97$	C $44.62 \pm .85$
Average weight of straw per culm of plant, in decigrams	Weight of straw per culm, in decigrams
M $10.190 \pm .129$	M $10.781 \pm .109$
σ $3.317 \pm .091$	σ $4.731 \pm .077$
C $32.55 \pm .99$	C $43.88 \pm .84$
Average weight of kernels per plant, in milligrams	Weight of kernels per culm, in milligrams
M $14.080 \pm .066$	M $13.851 \pm .058$
σ $1.684 \pm .046$	σ 2.540 ± 041
C $11.96 \pm .33$	C $18.34 \pm .31$

The mean for average height of plant in centimeters is less by $1.288 \pm .378$ than is that for height of culm. The standard deviation in the former case is less by $3.057 \pm .266$, and the coefficient of variability by $4.82 \pm .46$. These figures indicate that the culm is slightly higher when

culms are considered as units than when plants are considered as units, and that variability is greater by a large amount in the former case.

The mean for average number of kernels per culm of plant is less by 2.883 ± .986 than is that for number of kernels per culm. The standard deviation in the former case is less by 9.554 ± .696, and the coefficient of variability is less by 14.72 ± 1.43. These figures indicate that the average for number of kernels is slightly less, and the variability very much less, when plants are considered as the units of measurement.

The mean for average number of spikelets per culm of plant is less by 1.552 ± .518 than is that for number of spikelets per culm. The standard deviation in the former case is less by 4.604 ± .366, and the coefficient of variability is less by 12.45 ± 1.29. These figures indicate that the average for number of spikelets is very slightly less, and the variability very much less, when plants are used as the units of measurement.

The mean for average weight of straw per culm of plant is less by .591 ± .169 than is that for weight of straw per culm. The standard deviation in the former case is less by 1.414 ± .119, and the coefficient of variability is less by 11.33 ± 1.30. These figures indicate that the average for weight of straw is less by a slight amount, and variability is less by a large amount, when plants are used as the units of measurement.

The mean of average weight of kernels per plant in milligrams is 14.080 ± .066. The mean of weight of kernels per culm is 13.851 ± .058. The weight of kernels per plant in milligrams is greater by .229 ± .088 milligrams, which is less than three times the probable error. The standard deviation for average weight of kernels per plant is 1.684 ± .046, for average weight of kernels per culm 2.540 ± .041. The coefficients of variability are, respectively, 11.96 ± .33 and 18.34 ± .31. These figures denoting variability are greater for the kernels per culm than for the kernels per plant, coinciding in this with the figures for all other characters here considered; but the values of the means are reversed, being here, in the only instance, higher for a character when plants are used as the units of measurement.

The means here determined are remarkably close together in value. With one exception, however — this being for average weight of kernels —

the means for all characters are greater for the individual culms than for the average per culm of plant. It may be concluded, then, that for statistical work with oats practically the same means for the different characters will be obtained whether the plants are used as units — the

TABLE 2. CORRELATIONS, SERIES 1221 AND 22. PLANTS OR CULMS AS UNITS

Series 1221	Series 22
Average yield of culm per plant, in decigrams — Average height of plant, in centimeters r = .853 ± .011	Total yield of culm, in decigrams — Total height of culm, in centimeters r = 854 ± .006
Average yield of culm per plant, in decigrams — Average number of kernels per culm of plant r = .952 ± .004	Total yield of culm, in decigrams — Total number of kernels per culm r = .957 ± 002
Average yield of culm per plant, in decigrams — Average number of spikelets per culm of plant r = .931 ± .005	Total yield of culm, in decigrams — Total number of spikelets per culm r = .938 ± .003
Average yield of culm per plant, in decigrams — Average weight of straw per culm of plant, in decigrams r = .856 ± 010	Total yield of culm, in decigrams — Total weight of straw per culm, in decigrams r = .872 ± .006
Average yield of culm per plant, in decigrams — Average weight of kernels per plant, in milligrams r = .493 ± .029	Total yield of culm, in decigrams — Average weight of kernels per culm, in milligrams r = .573 ± .015
Average weight of kernels per plant, in milligrams — Average height of plant, in centimeters r = .325 ± .035	Average weight of kernels per culm, in milligrams — Total height of culm, in centimeters r = .431 ± .019
Average weight of kernels per plant, in milligrams — Average number of kernels per culm of plant r = .250 ± .036	Average weight of kernels per culm, in milligrams — Total number of kernels per culm r = .380 ± .020

average per culm being here determined — or the culms of the same plants are used as units; but that the means will generally be slightly greater for the culms as units.

The measures of variation, however — the standard deviations and the coefficients of variability — both indicate, consistently throughout, a

greater amount of variability where the culms are used as units; in other words, there is less variability in the averages of culm per plant than in the culms making up the plants.

Correlations

In order to obtain a comparison of the correlations that exist when the plant is used as the unit and when the separate culms of the same plant are used individually as the units, seven correlation coefficients were determined for each of the series. The correlation tables are shown in Figs. 72 to 85. The characters correlated and the coefficients determined are given in Table 2. A summary of the differences between the coefficients for the same correlated characters in the two lines is given in Table 3:

TABLE 3. SUMMARY OF DIFFERENCES IN CORRELATION COEFFICIENTS FOR THE SAME CHARACTERS IN THE TWO LINES COMPARED

Characters correlated	Difference	Difference / P. E. difference
Yield and height	001 ± .012	0.1
Yield and number of kernels	.005 ± .004	1.2
Yield and number of spikelets	.007 ± .006	1.2
Yield and weight of straw	.016 ± .012	1.3
Yield and average weight of kernels	080 ± .034	2.4
Average weight of kernels and height	.106 ± .040	2.6
Average weight of kernels and number of kernels	.130 ± .041	3 2

Comparing the coefficients of correlation given in Table 2, it is seen that they are almost identical in the cases when yield is correlated with height, number of kernels, number of spikelets, and weight of straw. the differences in these cases being, respectively, .001 ± .012, .005 ± .004, .007 ± .006, .016 ± .012. The difference in every case is thus seen to be either less than, or practically equal to, the probable error. Of these four pairs of correlation coefficients, those that are most nearly identical are those for yield and height. In series 1221 this coefficient is .853 ± .011, and in series 22 it is .854 ± .006 — a difference of only .001 ± .012, which is but one twelfth its probable error. The correlation

coefficients among these four pairs that differ most are for yield of culm and weight of straw. These are .856 ± .010 for series 1221 and .872 ± .006 for series 22. The difference here is .016 ± .012, which is but little larger than its probable error.

Somewhat large differences are found when average weight of kernels is considered in its relation to other characters. For yield and average

Series 1221

	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	Totals
0– 1	1										1
1– 2	1		1								2
2– 3	1			2							3
3– 4		2	8	6	1						17
4– 5			14	8	3						25
5– 6			8	17	8	1					34
6– 7		1	3	10	26	6					46
7– 8				4	25	13	1				43
8– 9					9	19	2				30
9–10				1	4	19	6				30
10–11					4	14	12	1			31
11–12						7	3	3			13
12–13					1		3	3	1		8
13–14							3	2			5
14–15							1	3			4
15–16							2	1			3
16–17									2		2
17–18										1	1
18–19									1		1
19–20								1			1
Totals	3	3	34	48	81	79	33	14	4	1	300

FIG. 72.—*Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative*

r = .853 ± .011

weight of kernels, the coefficients are .493 ± .029 in series 1221 and .573 ± .015 in series 22; the difference here being .080 ± .034, or a little more than twice its probable error. For average weight of kernels and height, the coefficients are .325 ± .035 in series 1221 and .431 ± .019 in series 22; the difference here being .106 ± .040. For average weight of kernels and number of kernels, the coefficients are .250 ± .036 in series 1221 and .380 ± .020 in series 22; the difference here being .130 ± .041, or a little more than three times its probable error.

If all the pairs of coefficients of correlation are compared (Table 3), it is seen that there are but three pairs which differ by a greater amount than .016, or by an amount greater than practical equality with their probable errors. In the three pairs in which the difference is greater,

Series 22

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	Totals
0– 1	1	7	8	4	4									24
1– 2		1	13	6	2	4	1	3						30
2– 3	1		2	20	12	5	5	1						46
3– 4				6	30	17	10	2						65
4– 5				2	21	26	14	4						67
5– 6				1	6	30	30	5	1					73
6– 7					4	14	19	12	2					51
7– 8					1	10	32	18	6	2	2			71
8– 9						5	15	34	19	1				74
9–10						1	19	34	21	6				81
10–11							3	18	19	14				54
11–12							1	10	23	8	1			43
12–13							2	5	18	11	1			37
13–14								3	13	13	4			33
14–15							1	1	12	6	3	1		24
15–16								3	3	14	6	1		27
16–17									3	7	7	1	2	20
17–18									2	6	2	2		12
18–19										4	4	2		10
19–20										2	2	1		5
20–21										1	3	2		6
21–22										1		1		2
22–23									1		1	2		4
23–24										1	1			2
28–29											1			1
Totals	2	8	23	39	80	112	152	153	143	97	38	13	2	862

FIG. 73.*— *Correlation between total yield of culm, in decigrams, subject; and total height of culm, in centimeters, relative*

r = .854 ± 006

*In this figure and in others marked with an asterisk, the classes containing no individuals are omitted in the publication but were taken into account in the calculations.

there is no case when it is greater than about three times the probable error, the greatest difference being .130 ± .041. These differences are not great, but in every one of the seven cases the higher coefficient of the pair is in series 22, or when the culms are used as the units of measurement. A certain small significance may therefore be attached to these differences.

Series 1221

	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	72–76	76–80	80–84	84–88	88–92	92–96	96–100	100–104	112–116	116–120	132–136	Totals
0–1	1																											1
1–2		2																										2
2–3			1		2																							3
3–4				3	9	4		1																				17
4–5					1	5	13	2	3	1																		25
5–6							9	9	8	6	2																	34
6–7								2	12	14	3	10	4		1													46
7–8								1	1	2	11	16	8	3		1												43
8–9											1	6	9	10	3	1												30
9–10												1	2	13	6	5	3											30
10–11													1	1	2	7	9	8	2		1							31
11–12														1	2		1	6	2	1								13
12–13																	1	1	3	3								8
13–14																1			1	1		2						5
14–15																		1			1	1		1				4
15–16																	1					1	1					3
16–17																							1	1				2
17–18																									1			1
18–19																										1		1
19–20																											1	1
Totals	1	2	1	3	12	9	22	15	24	23	17	33	24	28	14	15	15	16	8	5	2	4	2	2	1	1	1	300

FIG. 74.*—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative*

$r = .952 \pm .004$

*See footnote to Fig. 73, page 955.

Series 22

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	72–76	76–80	80–84	84–88	88–92	92–96	96–100	100–104	104–108	108–112	112–116	116–120	120–124	124–128	128–132	132–136	136–140	140–144	144–148	Totals
0–1	5	8	8	2	1																																	24
1–2		2	4	14	5	1	2	2																														30
2–3				3	15	16	.9	3																														46
3–4					2	17	20	10	11	4			1																									65
4–5							3	18	20	14	7	1	1	2		1																						67
5–6								3	16	16	19	10	5	1	3																							73
6–7										7	6	19	5	4	6	1	2			1																		51
7–8								1			5	8	26	7	11	6	4	2							1													71
8–9												1	4	12	18	20	13	4	1		1																	74
9–10											1			2	12	18	16	10	10	4	6	2																81
10–11											1				2	3	11	11	10	8	5	1	2															54
11–12														1	1		4	4	6	11	8	4	1	1	1	1												43
12–13																	1	1	5	5	10	7	3	5														37
13–14																		1	3	2	3	2	5	5	7	1	3	1										33
14–15																			2		1	2	5	6	1	1	2	2	2									21
15–16																			1				2	4	12	3	4	1										27
16–17																					1	1			5	3	2	4	1	1	2							20
17–18																							1			2	5	2	1	1								12
18–19																												3	3	2	2							10
19–20																												1	1	2			1					5
20–21																									1					2	2		1					6
21–22																												1									1	2
22–23																							1										1	2				4
23–24																										1										1		2
28–29																																			1			1
Totals	5	10	12	19	23	34	34	37	47	41	39	39	42	29	53	49	51	33	38	31	35	19	20	21	28	12	16	15	8	8	6	0	3	2	1	1	1	862

FIG. 75.*—*Correlation between total yield of culm, in decigrams, subject; and total number of kernels per culm, relative*

r = .957 ± .002

*See footnote to Fig. 73, page 955.

Series 1221

	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	36–38	38–40	40–42	42–44	44–46	46–48	48–50	50–52	52–54	54–56	56–58	58–60	60–62	64–66	70–72	Totals
0– 1	1																													1
1– 2	2																													2
2– 3		1			2																									3
3– 4			1	5	9		1	1																						17
4– 5				1	3	9	5	4	2	1																				25
5– 6				2	1	2	6	6	9	7	1																			34
6– 7							1	2	16	7	7	8	3	1	1															46
7– 8							2			7	11	10	10	1	2															43
8– 9											3	4	10	7	4	2														30
9–10											1	1	3	7	7	5	3	3												30
10–11												1		2	3	6	5	9	3	1			1							31
11–12												1	1		1		2	3	3		1	1								13
12–13																		1	3	3	1									8
13–14															1			1		1		1	1							5
14–15																	1				1		1		1					4
15–16															1							1		1						3
16–17																								2						2
17–18																											1			1
18–19																												1		1
19–20																													1	1
Totals	3	1	1	8	15	11	15	13	27	22	23	25	27	18	20	13	11	17	9	5	3	3	3	3	1	0	1	1	1	300

FIG. 76.*—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative*

$r = .931 \pm .005$

* See footnote to Fig. 73, page 955.

Series 22

	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	30-32	32-34	34-36	36-38	38-40	40-42	42-44	44-46	46-48	48-50	50-52	52-54	54-56	56-58	58-60	60-62	62-64	64-66	66-68	68-70	70-72	72-74	74-76	76-78	78-80	Totals
0-1	1	6	4	6	4	1	2																																		24
1-2			1	9	5	5	5	2	2		1																														30
2-3					3	6	12	12	8	2	2		1																												46
3-4						2	5	14	22	9	6	4	1	1	1																										65
4-5								2	9	18	14	14	4	2		4																									67
5-6								1	2	6	9	18	15	13	3	3	2	1																							73
6-7											3	5	8	8	12	3	6	1	4		1																				51
7-8								1	1			2	7	10	13	12	8	7	5	1	3					1															71
8-9													2	3	8	9	12	16	9	8	4	3																			74
9-10												1		1		3	11	16	15	12	9	2	5	5					1												81
10-11												1				2	1	4	5	8	12	11	4	3	3																54
11-12																2		2	2	5	4	7	7	7	3	1		2		1											43
12-13																	1	1		2	5	3	9	6	3	3	3	1													37
13-14																1				3	2	2	1	4	5	5	4	1	3	1	1										33
14-15																			1	1	1			2	5	4	3	2		2	1	1	1								24
15-16																				1					3	4	6	7	1	2	3										27
16-17																					1		1		2	3	2	2	1	4	1	1		1		1					20
17-18																								1			1	5	3			1	1								12
18-19																													1	2	1	4	1		1						10
19-20																														1	1	2				1					5
20-21																											1				1	3			1						6
21-22																												1												1	2
22-23																							1											1	1			1			4
23-24																												1									1				2
28-29																																			1						1
Totals	1	6	5	15	12	14	24	32	44	35	35	45	38	38	37	39	41	48	41	41	42	28	28	28	24	21	20	22	10	13	9	12	3	2	4	2	1	1	0	1	862

FIG. 77.*— *Correlation between total yield of culm, in decigrams, subject; and total number of spikelets per culm, relative*

r = .938 ± .003

*See footnote to Fig. 73, page 955.

Series 1221

	4– 5	5– 6	6– 7	7– 8	8– 9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	22–23	24–25	Totals
0– 1	1																			1
1– 2		2																		2
2– 3	1	1		1																3
3– 4		5	7	3	2															17
4– 5	1	2	12	5	1	2	2													25
5– 6			9	16	5	2		2												34
6– 7				19	12	10	3	1			1									46
7– 8				5	10	15	5	2	2	1	2		1							43
8– 9						12	11	2	4	1										30
9–10						3	12	7	3	2	2	1								30
10–11							9	5	6	8	1			1	1					31
11–12								4	3		2	2	1		1					13
12–13									1	3	1	1		1					1	8
13–14										1		2	1					1		5
14–15													2		2					4
15–16											1	1	1							3
16–17														1		1				2
17–18																	1			1
18–19																	1			1
19–20																	1			1
Totals	3	10	28	49	30	44	42	23	19	16	10	7	6	3	4	1	3	1	1	300

FIG. 78.*—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative*

$r = .856 \pm .010$

* See footnote to Fig. 73, page 955.

	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	24–25	25–26	26–27	27–28	28–29	29–30	30–31	31–32	32–33	33–34	34–35	Totals
0– 1	3	6	10	4	1																													24
1– 2		5	11	5	1	4	1	2	1																									30
2– 3	1	1	12	18	6	3	2		2		1																							46
3– 4			4	30	16	8	1	1	1	2				2																				65
4– 5			1	11	24	13	10	2	4	1		1																						67
5– 6				1	17	28	12	9	4	1	1																							73
6– 7					3	10	15	11	3	6	1	2																						51
7– 8					1	7	19	18	11	4	1	1	3	1	2	1		2																71
8– 9						1	12	19	18	11	5	5	2			1																		74
9–10							1	20	26	15	9	3	2	2		3																		81
10–11								1	8	17	16	6	5		1																			54
11–12									6	9	9	7	3	3	3		2										1							43
12–13								1	1	5	6	10	5	3	1	2		1		1					1									37
13–14											6	5	9	7	1	3	2																	33
14–15											3	3	5	2	3	1	2	2	1	2														24
15–16											1	2	5	5	6	1	4	1	1						1									27
16–17													1	2	1	6	2	1		2	1	1	1								2			20
17–18													1	3	1		2		2	1			1	1										12
18–19															1		2	3	1	1	1									1				10
19–20																1	1		1	2														5
20–21																	1	1	1	1	1		1											6
21–22																					1								1					2
22–23																		1			2	1												4
23–24																			1		1													2
28–29																																	1	1
Totals	4	12	38	69	69	71	73	84	85	71	59	45	41	30	20	19	18	12	8	10	7	2	3	1	2	0	1	0	1	1	2	0	1	862

FIG. 79.*— *Correlation between total yield of culm, in decigrams, subject; and total weight of straw per culm, in decigrams, relative*

r = .872 ± .006

*See footnote to Fig. 73, page 955.

Series 1221

	7– 8	8– 9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	Totals
0– 1	1															1
1– 2			1	1												2
2– 3			1		1		1									3
3– 4				1	1	5	6	3	1							17
4– 5				2	4	6	6	5	2							25
5– 6				1	4	5	10	5	6	2	1					34
6– 7				2	4	10	7	14	7	2						46
7– 8				1	2	4	12	19	3	1			1			43
8– 9					2	1	9	12	4	2						30
9–10						2	6	10	10	1	1					30
10–11					2	3	6	14	4	1	1					31
11–12							1	5	4	1	1		1			13
12–13								3	4	1						8
13–14								2	1		1		1			5
14–15								1	2			1				4
15–16									1	1					1	3
16–17									1	1						2
17–18									1							1
18–19									1							1
19–20								1								1
Totals	1	0	2	8	20	36	64	94	52	13	5	1	3	0	1	300

FIG. 80.—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative*

$r = .493 \pm .029$

Series 22

	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	24–25	25–26	Totals
0–1	1	2	4	2	6		2	4	1				2											24
1–2			2	3	2	2	4	3	5	5	1	2		1										30
2–3					1	1	7	4	8	7	11	3	2	1		1								46
3–4				1	1	1	5	5	10	13	6	13	8	1	1									65
4–5					4			7	4	20	11	10	8	2	1									67
5–6							1	5	6	15	13	15	11	5	1	1								73
6–7						1	1	3	8	5	13	9	6	5										51
7–8						1		3	5	14	8	21	9	7	2								1	71
8–9							1		5	9	18	25	8	5	2	1								74
9–10								1	7	16	11	20	18	5	1	1				1				81
10–11									2	7	9	17	12	3	3						1			54
11–12								1	1	2	12	11	7	6	1		1	1						43
12–13										3	5	9	13	3	3	1								37
13–14										4	6	11	4	3	2	3								33
14–15										3	3	3	7	5	1		2							24
15–16												5	13	8				1						27
16–17											3	2	6	6	1		2							20
17–18												1	3	7			1							12
18–19												1	4	4	1									10
19–20													2	2	1									5
20–21													1	3	1			1						6
21–22												1					1							2
22–23														2	1						1			4
23–24														1						1				2
28–29																		1						1
Totals	1	2	6	6	14	6	21	36	62	123	130	179	144	85	23	8	7	4	0	2	2	0	1	862

FIG. 81.*— *Correlation between total yield of culm, in decigrams, subject; and average weight of kernels per culm, in milligrams, relative*

$r = .573 \pm .015$

*See footnote to Fig. 73, page 955.

Series 1221

	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	Totals
7– 8	1										1
8– 9											0
9–10	1			1							2
10–11			2	1	2	2	1				8
11–12			4	4	4	7		1			20
12–13			7	9	9	9	2				36
13–14	1	2	10	9	19	17	6				64
14–15		1	4	17	32	23	10	6	1		94
15–16			5	7	9	15	8	5	2	1	52
16–17			2		4	3	2	1	1		13
17–18					1	2	2				5
18–19							1				1
19–20					1	1		1			3
20–21											0
21–22							1				1
Totals	3	3	34	48	81	79	33	14	4	1	300

FIG. 82.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative*

r = 325 ± .035

Series 22

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	Totals
3– 4		1												1
4– 5				1	1									2
5– 6			1	2	1	1		1						6
6– 7			1	1		1	1	2						6
7– 8	1	2	2	2	1		2	4						14
8– 9				2		1	1	1		1				6
9–10		2	4	3	3	2	4	1	2					21
10–11		2	2	3	6	6	12	2	1		2			36
11–12	1		3	6	5	12	12	12	9	2				62
12–13			5	8	18	20	24	20	17	9	2			123
13–14		1	1	4	19	22	19	24	28	11			1	130
14–15			1	3	14	22	40	37	34	21	5	1	1	179
15–16			2	2	8	15	23	27	29	26	10	2		144
16–17			1	1	4	7	9	12	12	17	14	8		85
17–18						2	3	3	6	6	2	1		23
18–19				1		1		4	1	1				8
19–20							1	1	1	2	1	1		7
20–21									2		2			4
22–23								1		1				2
23–24								1	1					2
25–26							1							1
Totals	2	8	23	39	80	112	152	153	143	97	38	13	2	862

FIG. 83.*— *Correlation between average weight of kernels per culm, in milligrams, subject; and total height of culm, in centimeters, relative*

r = .431 ± .019

*See footnote to Fig. 73, page 955.

Series 1221

	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	72–76	76–80	80–84	84–88	88–92	92–96	96–100	100–104	112–116	116–120	132–136	Totals
7–8	1																											1
8–9																												0
9–10		1			1																							2
10–11		1						1	2		1		1		1	1												8
11–12					1	1	3	1	1	2	1	2	3	1	1	1			1		1							20
12–13					3	2	3	1	2	5	2	8	2	2	1	2		2	1									36
13–14			1		5	2	5	5	5	6		8	7	6	2	2	4	5		1								61
14–15				2	1	3	3	3	7	8	10	12	5	9	4	6	8	4	2	3		2		1			1	94
15–16				1	1	1	5	2	5	2	2	1	5	7	3	2	1	4	3	1	1	1	1	1	1	1		52
16–17							2	1	2		1	1		2	1		1					1	1					13
17–18							1					1	1		1				1									5
18–19																		1										1
19–20								1						1		1												3
20–21																												0
21–22																	1											1
Totals	1	2	1	3	12	9	22	15	24	23	17	33	24	28	14	15	15	16	8	5	2	4	2	2	1	1	1	300

FIG. 84.*— *Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative*

$r = .250 \pm .036$

* See footnote to Fig. 73, page 955.

Series 22

	0– 4	4– 8	8– 12	12– 16	16– 20	20– 24	24– 28	28– 32	32– 36	36– 40	40– 44	44– 48	48– 52	52– 56	56– 60	60– 64	64– 68	68– 72
3– 4		1																
4– 5			2															
5– 6	1		1	1	1		2											
6– 7		1		1		1		2					1					
7– 8	2		4	1	1			1		1			1	2		1		
8– 9					2			1		1								
9–10		2	1	3		4	2	1	3	2					1		1	
10–11	1	2	1	1	2	1	3	2	3	1	5	2	1	1	3	1	2	2
11–12		1		5	2	2	5	4	6	3	1	3	3	3	5	1	4	3
12–13			2	3	3	6	7	5	8	9	10	7	4		10	5	8	5
13–14		1			6	6	5	4	6	6	7	11	5	5	5	10	8	5
14–15			1	2	2	7	7	5	9	7	6	9	15	6	12	17	15	7
15–16	1	1		1	2	6	2	6	8	6	3	3	7	6	9	11	7	6
16–17		1			1	1		3	4	5	3	3	3	3	5	2	4	3
17–18					1		1	1			2		2	1	2	1	1	1
18–19				1				1				1		1			1	1
19–20															1			
20–21														1				
21–22																		
22–23											1							
23–24											1							
24–25																		
25–26								1										
Totals	5	10	12	19	23	34	34	37	47	41	39	39	42	29	53	49	51	33

	72– 76	76– 80	80– 84	84– 88	88– 92	92– 96	96–100	100–104	104–108	108–112	112–116	116–120	120–124	128–132	132–136	136–140	140–144	144–148	Totals
3– 4																			1
4– 5																			2
5– 6																			6
6– 7																			6
7– 8																			14
8– 9		1					1												6
9–10			1																21
10–11				1				1											36
11–12	1	2	4	2	1		1												62
12–13	8	3	7		2	4			3	2	2								123
13–14	7	5	7	5	2	2	5	2	1	1		1	2						130
14–15	7	11	4	5	5	6	3	1	4	2	1	1	1					1	179
15–16	4	7	8	3	3	5	10	3	3	5	2	3	1	2					144
16–17	3	1	2	2	5	4	6	4	5	2	3	2	2		2		1		85
17–18	3	1	1				1			2		1		1					23
18–19	2																		8
19–20	2		1	1	1					1									7
20–21	1						1									1			4
21–22																			0
22–23								1											2
23–24					1														2
24–25																			0
25–26																			1
Totals	38	31	35	19	20	21	28	12	16	15	8	8	6	3	2	1	1	1	862

FIG. 85.*—*Correlation between average weight of kernels per culm, in milligrams, subject; and total number of kernels per culm, relative*

$$r = .380 \pm .020$$

*See footnote to Fig 73, page 955.

It can be said, from the results here shown, that practically the same correlation coefficients will be obtained when plants are used as the units of calculations as when the separate culms making up these plants are used as the units, but that there is a uniform tendency for the correlation to be greater when culms are used as the units. Greater differences exist in the correlation when average weight of kernels enters as one of the characters, but none of the differences found are great enough to be of special significance. The correlation coefficients obtained by the several investigators, therefore, whether they worked with culms or with plants, are comparable, with slight reservation, as far as any effect of this usage is concerned. The same may be said for the means, the standard deviations, and the coefficients of variability. All these constants, however, are generally slightly higher when the separate culms are the units than when the plants are the units.

Biometrical comparison of varieties of oats

The results obtained by Waldron (1910) in biometrical work with oats differed radically from those obtained by the writer (1911). The correlations obtained by Waldron between average weight of grain and number of grains per head, length of culm, and length of head, were of considerable value, amounting to forty to sixty per cent, and were negative. Those obtained by the writer for the same characters were large and positive. Some explanation of these discordant results was sought. One suggestion was that the use of different varieties had been the cause. In order to test the theory that correlations may be affected by varietal differences, pure lines of four different varieties were grown side by side under similar conditions during the season of 1911. These pure lines had been grown for several years by the Department of Plant-Breeding in the comparative rod-row tests that it was conducting. Fifteen-gram lots of seed were sown in eighteen-foot rows, and the rows were a foot apart. The varieties used were as follows:

Series	Variety	Pure line
1200	Great American	125–20
1219	Early Champion	137–6
1238	Welcome	123–5
1257	Sixty Day	62–II–6–3

These varieties were all sown on the same day, but were harvested as they ripened. The dates of harvesting and the figures showing thickness of stand are:

Variety	Harvested	Thickness of stand
Great American	July 24, 1911	400 plants in 15 feet = 26.7 plants per foot
Early Champion	July 24, 1911	600 plants in 18 feet = 33.3 plants per foot
Welcome	August 4, 1911	325 plants in 14 feet = 23.2 plants per foot
Sixty Day	July 24, 1911	610 plants in 18 feet = 33 9 plants per foot

It is seen that the Early Champion and the Sixty Day plants were somewhat more crowded in the row than were the Great American and the Welcome. By referring to Table 4, where are given the means for average weight of kernels per plant, it is seen that the means for Early Champion and Sixty Day are $10.913 \pm .115$ and $13.067 \pm .093$ milligrams, respectively, and for Great American and Welcome they are $22.640 \pm .172$ and $25.413 \pm .155$ milligrams, respectively. The latter two are thus seen to have much larger kernels than the former two, which accounts for the fewer plants growing in the rows of these varieties, since fifteen grams of each variety were sown in rows of the same length.

The size of kernel is a varietal characteristic and is not so much affected by crowded growing conditions as is any other character except height, as will be shown in another part of this paper.

Since the growing conditions of these varieties were slightly different, due to the growing of different numbers of plants in the rows, the differences that are observed in the means and the standard deviations are not surely due to varietal differences. They should be the same, however, as would be obtained were the plants taken from fields where seeding had been at a uniform rate of bushels per acre for different varieties, as has been done by some experimenters.

At the above rate of seeding and under the other conditions of growth, few plants of either of the varieties produced more than one culm per plant. The frequency distributions for numbers of culms per plant are as follows:

Variety	Number of culms per plant		
	1	2	3
1200	300	...	..
1219	295	5	...
1238	295	5	....
1257	288	11	1

It is seen here that in 1200 plants, taken without selection from the rows, there were but 1223 culms.

The means (M), standard deviations (σ), and coefficients of variability (C) for six characters of these different varieties are given in Table 4.

Taking up for consideration first the average yield of culm per plant, it is seen that there is considerable difference in the means. The highest is in series 1238, it being $8.217 \pm .219$ decigrams; the lowest is $3.433 \pm .096$, in series 1219. For series 1200 the mean is $6.403 \pm .149$, and for series 1257 it is $3.950 \pm .102$. The average yield per culm, which is essentially yield per plant, is, then, for the varieties, in descending order of yield, Welcome, Great American, Sixty Day, Early Champion. The standard deviations follow exactly the same order as do the means, which would indicate that the greatest variation exists in series 1238 and the least in series 1219. The coefficients of variability, however, indicate a different condition. For series 1219 this is 72.04 ± 2.82; for series 1238 it is 68.54 ± 2.62; for series 1257 it is 66.53 ± 2.51; and for series 1200 it is 59.75 ± 2.15. The greatest variability is thus indicated by the coefficient of variability where the standard deviation indicates the least. After an inspection of the frequency distributions for the different series, one is inclined to consider the standard deviation as by far the better index of variability in this case.

TABLE 4.— MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIABILITY, SERIES 1200, 1219, 1238, 1257.* VARIETIES

	Average yield of culm per plant, in decigrams			
	1200	1219	1238	1257
M....	6 403 ± .149	3.433 ± 096	8 217 ± .219	3 950 ± 102
σ ..	3 826 ± 105	2 473 ± 068	5 632 ± 155	2 628 ± 072
C. .	59 75 ± 2 15	72 04 ± 2 82	68 54 ± 2 62	66 53 ± 2 51
	Average height of plant, in centimeters			
	1200	1219	1238	1257
M. ..	56.533 ± 362	55.850 ± 432	62 916 ± .507	49 566 ± .416
σ . .	9 304 ± 256	11 114 ± 306	13.041 ± 359	10 703 ± .294
C.. ..	16 46 ± 46	19 90 ± 57	20 73 ± .59	21 59 ± .62
	Average number of kernels per culm of plant			
	1200	1219	1238	1257
M.	26 387 ± 510	29.293 ± 695	30 213 ± 755	28 440 ± .663
σ	13 113 ± .361	17.867 ± 491	19 420 ± 534	17 054 ± .469
C	49 70 ± 1 67	60 99 ± 2.21	64 28 ± 2 39	59 96 ± 2 16
	Average number of spikelets per culm of plant			
	1200	1219	1238	1257
M...	14 120 ± .275	17 160 ± 359	16 587 ± 421	14 000 ± .330
σ	7.082 ± 195	9 230 ± .254	10 834 ± .298	8 475 ± .233
C .	50 16 ± 1.69	53 79 ± 1.86	65 32 ± 2 45	60.54 ± 2.19
	Average weight of straw per culm of plant, in decigrams			
	1200	1219	1238	1257
M....	8.653 ± .180	5 227 ± 107	9.767 ± 204	5.303 ± 116
σ .. .	4 632 ± 127	2 763 ± 076	5.250 ± 144	2 977 ± .082
C.....	53.53 ± 1 85	52 86 ± 1 81	53 75 ± 1 86	56 14 ± 1 97
	Average weight of kernels per plant, in milligrams			
	1200	1219	1238	1257
M. .	22.640 ± .172	10 913 ± .115	25 413 ± .155	13.067 ± 093
σ	4.417 ± 121	2 967 ± 082	3.983 ± .110	2 400 ± 066
C.....	19 51 ± 56	27.19 ± 80	15 67 ± .44	18.37 ± 52

*1200, Great American
1219, Early Champion
1238, Welcome
1257, Sixty Day

The means for average height of plant in centimeters vary among themselves less than for the character just considered. The mean for series 1238 is again the highest, being 62.916 ± .507. Series 1200 is again second highest, being 56.533 ± .362. The order of series 1219 and series 1257 is reversed, the former being here 55.850 ± .432, which is considerably larger than 49.566 ± .416, the mean of the latter. The short plant of the Sixty Day variety is without doubt a varietal characteristic. It seems likely also that the means for height of each of these varieties denote varietal differences. The greatest variability is again in series 1238, as is indicated by the standard deviation of 13.041 ± .359. The least variability in height occurs in series 1200, where the standard deviation is 9.304 ± .256. The short-culmed variety, the Sixty Day, has a standard deviation of 10.703 ± .294, and for series 1219 the standard deviation is 11.114 ± .306.

In average number of kernels per culm of plant the means of the different varieties are not far apart in value. The highest, 30.213 ± .755, is again for series 1238. The lowest, 26.387 ± .510, is for series 1200. Series 1219 is second in order, with a mean of 29.293 ± .695, and series 1257 is third with 28.440 ± .663. The standard deviations for the four series follow the same order of value as do the means, the largest being 19.420 ± .534 for series 1238 and the smallest 13.113 ± .361 for series 1200.

It is seen that the large differences do not exist in the means for number of kernels that exist in the means for yield, neither do the means follow the same order in amount. It is evident, therefore, that increase in yield is not due to a larger number of kernels per culm. The average yields per culm are more nearly proportional to the average weight of kernels per plant. By examining the means of the latter character it is seen that series 1238 has much the largest kernel, the mean being 25.413 ± .155. The mean for yield of the same series is also considerably above the means of the other series. The same condition exists throughout. Series 1219 has the smallest mean for yield and also the smallest mean for average weight of kernels, the latter being but 10.913 ± .115. The greatest variability, however, is in series 1200, where the standard deviation is 4.417 ± .121. The least variation is in series 1257, where the standard deviation is 2.400 ± .066.

The means for number of spikelets do not follow the same order of value as do the means of yield and average weight, neither is the order that of the number of kernels, although it is nearer the latter. Series 1219 here has the largest mean, it being 17.160 ± .359. Series 1257 has the smallest,

it being 14.000 ± .330. Series 1238 has the greatest amount of variability, however, the standard deviation here being 10.834 ± .298, while that nearest to it is 9.230 ± .254 for series 1219. The smallest standard deviation is 7.082 ± .195, for series 1200.

Since the means of number of spikelets are not proportional to the means of average yield, the same conclusions hold as were made when number of kernels was discussed. And again, since the means for number of spikelets are not directly proportional to those of number of kernels, it follows that the average number of kernels per spikelet must vary for different varieties. These values have not been determined from the original data, but it is evident from the means here determined that the Sixty Day oats have the largest number of kernels per spikelet and that the Early Champion oats have the smallest number. The remaining varieties have numbers of kernels per spikelet somewhere between these two.

The means for average weight of straw per culm of plant in decigrams follow the same order of value as do the means for average yield of culm per plant in decigrams. Series 1238 has the largest mean, 9.767 ± .204, while series 1219 has the smallest, 5.227 ± .107. For series 1200 and 1257 the means are 8.653 ± .180 and 5.303 ± .116, respectively. The standard deviations again follow the same order as do the means, being greatest in series 1238 and least in series 1219.

While there is a definite rise and fall in the means of the average weight of straw per culm of plant with increase and decrease in the means of the average yield of culm per plant for the different varieties here considered, the proportion of grain to straw is not the same for each variety. Considering the mean for average yield of culm per plant as unity in each case, the mean of average weight of straw per culm of plant is in the following proportions for the different varieties:

Great American........................	1 : 1.35
Early Champion........................	1 : 1.52
Welcome...............................	1 : 1.19
Sixty Day.............................	1 : 1.34

As the average yield of culm per plant increases, the proportion of straw to grain decreases for the different varieties, with the exception of the Sixty Day variety. In the Welcome variety the proportion of straw to grain is lower than in any of the others. It seems to be a varietal characteristic of the Welcome to produce less straw to the unit amount of grain.

Considerable difference is shown in average yield of culm per plant by the means determined. This may be due to the difference in stand, caused by the large size of kernels in certain varieties. The means of height of plant seem to denote some varietal differences. The larger yields from certain varieties are not due to a larger number of kernels per culm, or to a larger number of spikelets per culm, as the means for these characters are nearly the same for each variety. The yield per culm seems directly proportional to the average weight of kernels per plant. The average number of kernels per spikelet is largest in the Sixty Day variety and smallest in Early Champion. The proportion of straw to grain differs in the different varieties. As the average yield of culm per plant increases, the proportion of straw to grain decreases — not entirely regularly, however, for the different varieties.

The standard deviation is probably the better index of variability, when the same character of different varieties is being compared and when the same unit of measure has been used. Basing conclusions on this constant, then, it is seen that the greatest variability occurs in the Welcome variety for all characters considered, except average weight of kernels. In this character the variability of this variety is exceeded only by that of the Great American. The least variability occurs in Great American for height, number of kernels, and number of spikelets, in Early Champion for yield and for weight of straw, and in Sixty Day for average weight of kernels. Sixty Day is next to the lowest in variability in all characters considered, except average weight of kernels. The order of value of the standard deviations is the same as that of the means, for yield, number of kernels, and weight of straw; that is, the greatest variability in these characters is found where the means are largest, and decrease in variability takes place in the same order as decrease in means. In the number of spikelets the standard deviation is highest when the mean is next highest, and next highest when the mean is highest. The same condition exists for the lowest and the next lowest standard deviations. Exactly the same conditions hold for average weight of kernels as hold for number of spikelets. For height there is more complication, the lowest standard deviation being associated with the second highest mean, the second lowest standard deviation with the lowest mean, and the second highest standard deviation with the second lowest mean.

Correlations

Coming now to the correlations that exist in these several varieties, it is seen in Table 5 that seven correlation coefficients for each variety have been determined. These are grouped in the table in such a way that the coefficients for each variety are given under a single heading showing the characters correlated.

TABLE 5. CORRELATIONS, SERIES 1200, 1219, 1238, 1257.* VARIETIES

Average yield of culm per plant, in decigrams — Average height of plant, in centimeters			
1200	r = .866 ± .010	1238	r = .889 ± .008
1219	r = .859 ± .010	1257	r = .875 ± 009
Average yield of culm per plant, in decigrams — Average number of kernels per culm of plant			
1200	r = .959 ± .003	1238	r = 985 ± .001
1219	r = 934 ± .005	1257	r = 965 ± .003
Average yield of culm per plant, in decigrams — Average number of spikelets per culm of plant			
1200	r = 961 ± .003	1238	r = 985 ± .001
1219	r = .916 ± 006	1257	r = 954 ± .003
Average yield of culm per plant, in decigrams — Average weight of straw per culm of plant, in decigrams			
1200	r = 818 ± .013	1238	r = .944 ± 004
1219	r = .933 ± 005	1257	r = 925 ± .006
Average yield of culm per plant, in decigrams — Average weight of kernels per plant, in milligrams			
1200	r = .686 ± .021	1238	r = 596 ± .025
1219	r = .539 ± 028	1257	r = 563 ± .027
Average weight of kernels per plant, in milligrams — Average height of plant, in centimeters			
1200	r = .654 ± .022	1238	r = .575 ± .026
1219	r = .553 ± .027	1257	r = .577 ± .026
Average weight of kernels per plant, in milligrams — Average number of kernels per culm of plant			
1200	r = .524 ± .028	1238	r = .494 ± .029
1219	r = .340 ± .034	1257	r = .415 ± .032

* 1200, Great American
1219, Early Champion
1238, Welcome
1257, Sixty Day

For average yield of culm per plant correlated with average height of plant (Figs. 86 to 89), the coefficients are seen to be nearly equal for the several varieties. The highest, .889 ± .008 for series 1238, is but .030 ± .013 higher than the lowest, .859 ± .010 for series 1219. The extreme difference is a little more than twice its probable error.

Series 1200

	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	Totals
0– 1	2	3		1								6
1– 2		9	11	6	3							29
2– 3		1	7	12	4							24
3– 4			1	12	9	2		1				25
4– 5				3	22	13						38
5– 6				1	10	20	4					35
6– 7					5	17	10					32
7– 8						6	12	3				21
8– 9		1				6	12	5				24
9–10						2	8	7				17
10–11							6	8	1			15
11–12						1	2	4	3			10
12–13								2	6			8
13–14						1		3				4
14–15							1	1		1		3
15–16								1				1
16–17								1	1			2
17–18										1		1
18–19									1			1
19–20										3	1	4
Totals	2	14	19	35	53	68	55	36	12	5	1	300

FIG. 86.— *Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative. Great American*

r = 866 ± .010

Series 1219

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	Totals
0– 1	3	10	12	13	3								41
1– 2			1	13	25	17	3						59
2– 3					6	27	18	7	1				59
3– 4					1	6	17	12	1	1			38
4– 5						1	8	19	7				35
5– 6								7	13	4			24
6– 7							1	3	8	7	1		20
7– 8									5	4			9
8– 9									1	1	1		3
9–10									1	4	1		6
10–11										2			2
11–12											2		2
12–13													0
13–14											1	1	2
Totals	3	10	13	26	35	51	47	48	37	23	6	1	300

FIG. 87.— *Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative. Early Champion*

r = .859 ± .010

Series 1238

	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	95–100	100–105	Totals
0– 1	3		4	2	1											10
1– 2		5	8	4	3	1			1							22
2– 3			5	14	5	1	1									26
3– 4			1	3	12	7	2	2								27
4– 5				3	8	8	2	1								22
5– 6					4	10	4									18
6– 7					2	6	3	4	1	1						17
7– 8						2	13	8	1	1						25
8– 9						3	9	6		2						20
9–10							1	10	4							15
10–11							3	8	2	1						14
11–12						1		6	7	1	1					16
12–13								1	5	3						9
13–14								2	5	1	2	2				12
14–15								2	3	3	2					10
15–16									2	2	2	1				7
16–17						1					1	1				3
17–18										3	2		1			6
18–19									1	1	1	2				5
19–20										1	4					5
20–21											2	1				3
21–22											1					1
22–23											1		1			2
23–24												1	1			2
24–25												1				1
27–28															1	1
28–29														1		1
Totals	3	5	18	26	35	40	38	50	32	20	19	9	3	1	1	300

FIG. 88.*— *Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative. Welcome*

$r = .889 \pm .008$

*See footnote to Fig 73, page 955.

Series 1257

	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	Totals
0– 1	1	3	10	12	8							34
1– 2				4	16	20	5	1				46
2– 3						23	25	7				55
3– 4						2	15	17	2	1		37
4– 5						1	3	20	8	1		33
5– 6							1	4	14	8	2	29
6– 7							1		9	11	2	23
7– 8									5	8	3	16
8– 9									3	7	1	11
9–10									1	4	5	10
10–11									1		3	4
11–12											1	1
12–13											1	1
Totals	1	3	10	16	24	46	50	49	43	40	18	300

FIG. 89.—*Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative. Sixty Day*

r = .875 ± .009

When average yield of culm per plant is correlated with average number of kernels per culm of plant (Figs. 90 to 93), the difference in the coefficients is slightly greater. The highest, .985 ± .001 for series 1238, is .051 ± .005 higher than the lowest, .934 ± .005 for series 1219. This extreme difference, although small, is more than ten times its probable error.

Series 1200

	0– 4	4– 8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	68–72	72–76	76–80	Totals
0– 1	3	3																	6
1– 2		9	17	3															29
2– 3			10	13	1														24
3– 4				8	14	2	1												25
4– 5				2	20	12	4												38
5– 6					4	12	11	6	2										35
6– 7						4	10	17	1										32
7– 8						1	3	9	6	2									21
8– 9								11	7	4		1	1						24
9–10								1	7	6	2	1							17
10–11									4	5	5	1							15
11–12										5	3	1	1						10
12–13												4	4						8
13–14												3	1						4
14–15												1	1	1					3
15–16													1						1
16–17													1		1				2
17–18															1				1
18–19															1				1
19–20																2	1	1	4
Totals	3	12	27	26	39	31	29	44	27	22	10	12	10	1	3	2	1	1	300

FIG. 90.*—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative. Great American*

r = .959 ± .003

*See footnote to Fig. 73, page 955

Series 1219	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	72–76	76–80	80–84	84–88	88–92	92–96	Totals
0–1	8	17	11	5																					41
1–2		1	18	18	15	7																			59
2–3				6	5	19	20	6	3																59
3–4						9	1	6	12	6	4														38
4–5							4	3	5	12	5	4		1	1										35
5–6									1	4	2	4	2	8	2	1									24
6–7										3	1	3	5	2	5	1									20
7–8												1	1	2	3	1		1							9
8–9													1		1	1									3
9–10															2	1	2		1						6
10–11															1					1					2
11–12																		1					1		2
12–13																									0
13–14																				1				1	2
Totals	8	18	29	29	20	35	25	15	21	25	12	12	9	13	15	5	2	2	1	2	0	0	1	1	300

FIG. 91.—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative. Early Champion*

r = 934 ± 005

Series 1238

	0– 4	4– 8	8– 12	12– 16	16– 20	20– 24	24– 28	28– 32	32– 36	36– 40	40– 44	44– 48	48– 52	52– 56	56– 60	60– 64	64– 68	68– 72	72– 76	76– 80	80– 84	84– 88	88– 92	92– 96	96–100	Totals
0– 1	6	4																								10
1– 2	1	14	7																							22
2– 3			22	4																						26
3– 4			4	20	3																					27
4– 5				3	13	6																				22
5– 6					6	6	5		1																	18
6– 7					2	9	5		1																	17
7– 8						1	13	7	1	2	1															25
8– 9							5	8	5	2																20
9–10								5	8	1	1															15
10–11									5	5	3	1														14
11–12									1	7	7	1														16
12–13										1	5	2	1													9
13–14											1	3	6	2												12
14–15												1	7	2												10
15–16													1	4	1		1									7
16–17															2	1										3
17–18															1		4	1								6
18–19																2	1	1		1						5
19–20																	3	2								5
20–21																		1	2							3
21–22																			1							1
22–23																			2							2
23–24																					1	1				2
24–25																					1					1
25–26																										0
26–27																										0
27–28																								1		1
28–29																									1	1
Totals	7	18	33	27	24	22	28	20	22	18	18	8	15	8	4	3	9	5	5	1	2	1	0	.1	1	300

FIG. 92.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative Welcome*

$r = .985 \pm .001$

Series 1257

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	72–76	76–80	Totals
0– 1	12	17	5																		34
1– 2		2	17	18	8	1															46
2– 3			1	9	24	14	6		1												55
3– 4						9	18	5	3	2											37
4– 5						3	4	10	9	5		2									33
5– 6									8	9	9	1	1	1							29
6– 7										2	11	5	3		2						23
7– 8											2	1	6	3	4						16
8– 9													2	3	6						11
9–10															6	2		1	1		10
10–11																2	2				4
11–12																				1	1
12–13																				1	1
Totals	12	19	23	27	32	27	28	15	21	18	22	9	12	7	18	4	2	1	1	2	300

FIG. 93.—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative. Sixty Day*

$r = .965 \pm .003$

For average yield of culm per plant correlated with average number of spikelets per culm of plant (Figs. 94 to 97), there is an extreme difference of .069 ± .006 between the coefficients. Series 1238 is again highest, with .985 ± .001, and series 1219 is again lowest, with .916 ± .006. The difference is more than eleven times its probable error.

For average yield of culm per plant correlated with average weight of straw per culm of plant (Figs. 98 to 101), the highest coefficient is .944 ± .004, again for series 1238, and the lowest is .818 ± .013 for series 1200. The difference here, .126 ± .014, is nine times its probable error.

Series 1200

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	36–38	38–40	40–42	Totals
0– 1	2	4																				6
1– 2		6	18	4	1																	29
2– 3			7	15	2																	24
3– 4				5	14	4	1	1														25
4– 5					17	14	6	1														38
5– 6					1	11	12	7	4													35
6– 7						2	7	12	9	2												32
7– 8							2	8	6	5												21
8– 9								3	13	4	2	1	1									24
9–10								1	2	9	3	1	1									17
10–11										4	6	4	1									15
11–12											6	2	1		1							10
12–13												2	4	2								8
13–14												1	1	2								4
14–15														3								3
15–16														1								1
16–17														1		1						2
17–18																	1					1
18–19																	1					1
19–20																			1	1	2	4
Totals	2	10	25	24	35	31	28	33	34	24	17	11	9	9	1	1	2	0	1	1	2	300

FIG. 94.—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative. Great American*

r = .961 ± .003

Series 1219

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	36–38	38–40	40–42	42–44	44–46	46–48	48–50	Totals
0– 1	2	8	14	7	9	1																				41
1– 2			4	11	14	17	11	1	1																	59
2– 3				1	3	10	13	16	10	4	2															59
3– 4						3	2	6	4	6	10	5	2													38
4– 5							2	1	2	5	11	5	4	3	2											35
5– 6											5	1	4	4	5	4		1								24
6– 7									1	1	1	2	4	3	1	2	2	2		1						20
7– 8													1	2	2	1	2			1						9
8– 9																2		1								3
9–10																1	1	2	1			1				6
10–11																1					1					2
11–12																					1			1		2
12–13																										0
13–14																					1				1	2
Totals	2	8	18	19	26	31	28	24	18	16	29	13	15	12	10	11	5	6	1	2	3	1	0	1	1	300

FIG. 95.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative. Early Champion*

r = .916 ± 006

Series 1238

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	36–38	38–40	40–42	42–44	44–46	46–48	48–50	50–52	52–54	54–56	Totals
0– 1	6	3	1																										10
1– 2		13	9																										22
2– 3			16	9	1																								26
3– 4			2	16	8	1																							27
4– 5				1	11	8	2																						22
5– 6					3	7	5	2	1																				18
6– 7					1	6	8	1	1																				17
7– 8							7	9	6	1	2																		25
8– 9							1	6	9	3	1																		20
9–10									4	8	2	1																	15
10–11									2	3	8		1																14
11–12										1	5	8	2																16
12–13											1	2	6																9
13–14												1	1	6	4														12
14–15													2	6	1	1													10
15–16														1	1	3	1	1											7
16–17															1		2												3
17–18																	1		2	2	1								6
18–19																		2	2				1						5
19–20																		1	2	2									5
20–21																					3								3
21–22																					1								1
22–23																					1	1							2
23–24																							1	1					2
24–25																						1							1
27–28																										1			1
28–29																												1	1
Totals	6	16	28	26	24	22	23	18	23	16	19	12	12	13	7	4	4	4	6	4	6	2	2	1	0	1	0	1	300

Fig. 96.*—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative. Welcome*

r = .985 ± .001

*See footnote to Fig 73, page 955.

Series 1257

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	36–38	38–40	40–42	Totals
0– 1	12	16	6																			34
1– 2		1	16	18	8	3																46
2– 3				12	25	12	6															55
3– 4					4	11	11	8	1	2												37
4– 5						3	7	9	7	4	1	1	1									33
5– 6								3	9	7	7	1	1		1							29
6– 7									2	3	11	2	1	2	2							23
7– 8										2	2		7	2	2	1						16
8– 9													1	5	3	2						11
9–10													1		4	3	1			1		10
10–11														1		1	1	1				4
11–12																					1	1
12–13																				1		1
Totals	12	17	22	30	37	29	24	20	19	18	21	4	12	10	12	7	2	1	0	2	1	300

FIG. 97.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative. Sixty Day*

$r = .954 \pm .003$

Series 1200

	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	48–49	Totals
0–1	4	1	1																					6
1–2	4	11	10	1	2		1																	29
2–3		4	13	5	2																			24
3–4			4	16	2	1	1			1														25
4–5			1	6	22	7	2																	38
5–6				2	7	13	6	3	2		2													35
6–7					1	12	9	8	1			1												32
7–8						1	7	8	3	1		1												21
8–9						1	1	7	9	4	2													24
9–10								1	7	7			2											17
10–11								1	2	5	3	3			1									15
11–12										4	1	2			2	1								10
12–13												4		2					1				1	8
13–14												1	2	1										4
14–15													2				1							3
15–16														1										1
16–17														1		1								2
17–18																	1							1
18–19																			1					1
19–20																			1		1	2		4
Totals	8	16	29	30	36	35	27	28	24	22	8	12	6	5	3	2	2	0	3	0	1	2	1	300

FIG. 98.*— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative.* Great American

r = 818 ± 013

* See footnote to Fig. 73, page 955.

Series 1219

	0– 1	1– 2	2– 3	3– 4	4– 5	5– 6	6– 7	7– 8	8– 9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	Totals
0– 1	4	18	17	2													41
1– 2		3	26	21	8		1										59
2– 3			1	23	24	11											59
3– 4				1	6	23	3	4	1								38
4– 5					2	8	19	5	1								35
5– 6						2	5	8	5	3	1						24
6– 7								7	6	5	1				1		20
7– 8							1	2	3	2	1						9
8– 9									1	1	1						3
9–10											3	2	1				6
10–11												1	1				2
11–12														2			2
12–13																	0
13–14																2	2
Totals	4	21	44	47	40	44	29	26	17	11	7	3	2	2	1	2	300

FIG. 99.—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative. Early Champion*

r = .933 ± 005

Series 1238

	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	24–25	25–26	26–27	27–28	28–29	29–30	30–31	31–32	Totals
0–1	2	2	2	4																												10
1–2	1	3	11	5	1						1																					22
2–3			7	13	6																											26
3–4			1	5	6	9	5	1																								27
4–5				3	5	7	3	2	1							1																22
5–6					2	9	5	2																								18
6–7					1	3	5	6	1		1																					17
7–8						1	8	9	4		1			1			1															25
8–9							2	4	7	4		1		2																		20
9–10								1	3	4	3	3			1																	15
10–11							1	1		2	6	2	2																			14
11–12									1	1	4	4	2	4																		16
12–13											1		3	4	1																	9
13–14													4	3	3	1	1															12
14–15												2	3		4			1														10
15–16														1	3	1	1	1														7
16–17														1		1	1															3
17–18																2	1		1	1	1											6
18–19																1	1		1			1		1								5
19–20															1		1	1	1		1											5
20–21																			1	2												3
21–22																				1												1
22–23																					1				1							2
23–24																			1					1								2
24–25																							1									1
25–26																																0
26–27																																0
27–28																															1	1
28–29																											1					1
Totals	3	5	21	30	21	29	29	26	17	11	17	12	14	16	13	7	7	3	5	4	3	1	1	2	1	0	1	0	0	0	1	300

FIG. 100.—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative. Welcome*

$r = .944 \pm .004$

Series 1257

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	Totals
0–1	2	23	9																	34
1–2		7	23	11	4			1												46
2–3			5	36	13	1														55
3–4			1	5	18	12			1											37
4–5					4	20	6	2		1										33
5–6						4	10	9	4		1				1					29
6–7						1	5	6	6	4	1									23
7–8							1	6	4	3		1		1						16
8–9									4	3	3		1							11
9–10											6	2	2							10
10–11											2	2								4
11–12																	1			1
12–13																			1	1
Totals	2	30	38	52	39	38	22	24	19	11	13	5	3	1	1	0	1	0	1	300

FIG. 101.—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative. Sixty Day*
$r = .925 \pm .006$

For average yield of culm per plant and average weight of kernels per plant (Figs. 102 to 105), the highest coefficient is .686 ± .021 for series 1200, and the lowest is .539 ± .028 for series 1219. The difference here is .147 ± .035, which amounts to about four times its probable error.

Series 1200

	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	24–25	25–26	26–27	27–28	28–29	29–30	30–31	31–32	32–33	Totals
0– 1	1				2		1		1								1							6
1– 2	1	2	2	3	3	4	1	5	2	2		1	2		1									29
2– 3					2		6		3	3	5		1	2		1							1	24
3– 4				1	1		1	2		5	2	3	6	3				1						25
4– 5							1	1	3	3	5	5	7	7	1	2	1		2					38
5– 6							2	2	2	6	1	3	8	2	3	3		2		1				35
6– 7									1	1	8	5	3	1	4	4	2	2		1				32
7– 8									1	1	1	2	4	3	3	2			3	1				21
8– 9								2				2	2	2	1	6	3	2	2	1	1			24
9–10												1	2	1	2	3	4		1	3				17
10–11													1	2	1	1	3	3	2	1	1			15
11–12													1		1		1	1	2	2	1	1		10
12–13															2	2	1	1	2					8
13–14																	1	1	1		1			4
14–15																		1		2				3
15–16																					1			1
16–17																		1				1		2
17–18																			1					1
18–19																						1		1
19–20															1		1	2						4
Totals	2	2	2	4	8	4	12	12	13	21	22	22	37	23	20	24	18	17	16	12	5	3	1	300

FIG. 102.— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative. Great American*

r = 686 ± 021

Series 1219

	2- 3	3- 4	4- 5	5- 6	6- 7	7- 8	8- 9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	Totals
0- 1	1	4	4	5	8	6	3	4	1	2				2	1			41
1- 2				1	2	9	9	10	10	7	4	2	4	1				59
2- 3						2	8	15	9	11	3	3	2	3		1	2	59
3- 4							5	8	8	5	5	2	3	1	1			38
4- 5						1	1	1	12	5	6	3	2		1	2	1	35
5- 6								6	7	2	5	2	1	1				24
6- 7									4	3	5	1	2	4		1		20
7- 8										2	2	4		1				9
8- 9												1	1		1			3
9-10											1		2	2	1			6
10-11												1			1			2
11-12											1				1			2
12-13																		0
13-14												1			1			2
Totals	1	4	4	6	10	18	26	44	51	37	32	20	17	15	8	4	3	300

FIG. 103.—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative. Early Champion*

$r = .539 \pm .028$

Series 1238

	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	24–25	25–26	26–27	27–28	28–29	29–30	30–31	31–32	32–33	33–34	Totals
0–1	1					1			2		1	2	1	1					1									10
1–2						1			1	1	4	3	4	1	2	1	1		1	1		1						22
2–3											1	1	3	4		3	6	4	2	2								26
3–4											1		1	2	3	1	3	6	3	3	2			2				27
4–5												1	1	2	1	2	4	3	2	2	2	1			1			22
5–6									1					3	1	3	4		2	1	1		1	1				18
6–7													1					3	1	4	2	2	1	2			1	17
7–8												1		2	1			3	4	5	3	3		2	1			25
8–9																	3	2		2	4	1	4		1			20
9–10																	1		2	3	3	1	2	2	1			15
10–11																1		1	1	3		3	3	2				14
11–12																			2		5	4	3	2				16
12–13																				1	2	2	2	1		1		9
13–14																		1	3	4	1	2		1				12
14–15																				2	1	3	1	2	1			10
15–16																		1			4	1	1					7
16–17																			1			2						3
17–18																			1	3	1			1				6
18–19																	1				1	2	1					5
19–20																					1	2	2					5
20–21																					2		1					3
21–22																						1						1
22–23																							1	1				2
23–24																					1	1						2
24–25																							1					1
25–26																												0
26–27																												0
27–28																						1						1
28–29																						1						1
Totals	1	0	0	0	0	2	0	0	4	1	7	8	11	15	8	11	23	24	26	36	36	37	21	19	5	1	1	300

FIG. 104.— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative.* *Welcome*

r = .596 ± .025

Series 1257

	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	Totals
0–1		2	7	5	1	8	3	1	2	3	1	1		34
1–2	1		1	3	4	8	9	5	9	4		1	1	46
2–3			1		1	4	15	14	5	7	5	1	2	55
3–4					1	3	5	8	13	4	2	1		37
4–5				1		2	2	9	3	3	8		5	33
5–6						1	1	5	7	7	7	1		29
6–7							2	2	4	7	3	4	1	23
7–8								2	6	3	2	3		16
8–9									2	5	3	1		11
9–10									1	2	2	5		10
10–11										1		1	2	4
11–12											1			1
12–13											1			1
Totals	1	2	9	9	7	26	37	46	52	46	35	19	11	300

FIG. 105.—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative. Sixty Day*

$r = .563 \pm .027$

When the average weight of kernels per plant is correlated with the erage height of plant (Figs. 106 to 109), the highest coefficient is again ınd in series 1200, where it is .654 ± .022. The lowest is again in ies 1219, where it is .553 ± .027. The difference is here .101 ± .035, ıich appears rather large but in fact is less than three times its obable error.

ies 1200

	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	Totals
10–11	1	1										2
11–12			1		1							2
12–13			1	1								2
13–14			2		1			1				4
14–15	1	4		2		1						8
15–16		2	1	1								4
16–17		1	2	5	2	2						12
17–18		1	4	2	2	1	2					12
18–19		1	1	5	2	3	1					13
19–20		1	2	3	6	6	3					21
20–21			3	3	9	6	1					22
21–22			1	1	8	5	7					22
22–23				8	8	14	4	3				37
23–24			1	1	7	6	6	2				23
24–25		1			2	6	5	3	2	1		20
25–26		1		1	3	6	6	5	2			24
26–27		1		1		3	5	7			1	18
27–28				1		2	7	1	4	2		17
28–29					1	5	1	7	1	1		16
29–30						2	6	2	1	1		12
30–31							1	4				5
31–32								1	2			3
32–33					1							1
Totals	2	14	19	35	53	68	55	36	12	5	1	300

Fig. 106.—*Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative. Great American*

r = .654 ± .022

Series 1219

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	Totals
2– 3	1												1
3– 4	2	2											4
4– 5		1	3										4
5– 6		1	3		1		1						6
6– 7		3	2	3	2								10
7– 8		2	1	5	3	4	2		1				18
8– 9			1	3	7	8	2	2	2	1			26
9–10			2	1	7	10	13	6	4	1			44
10–11			1	4	3	11	9	11	9	3			51
11–12				7	2	6	9	7	3	3			37
12–13					3	3	3	11	7	4	1		32
13–14					3	2	3	3	3	4	2		20
14–15				1	2	3	2	3	3	2	1		17
15–16		1		1	1	2	1	2	3	3	1		15
16–17				1		1		1	1	2	1	1	8
17–18					1		1	1	1				4
18–19						1	1	1					3
Totals	3	10	13	26	35	51	47	48	37	23	6	1	300

FIG. 107.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative. Early Champion*

$r = 553 \pm .027$

Series 1238

	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	95–100	100–105	Totals
7–8			1													1
12–13				2												2
15–16	1		2				1									4
16–17			1													1
17–18		1	1	3	1				1							7
18–19	1	1	1	3	1		1									8
19–20		1	2	3	3	1		1								11
20–21	1	1	2	2	4	2	1	1		1						15
21–22			1	1	3	1	2									8
22–23		1		1	3	3	2			1						11
23–24			2	3	3	9	3	1	1			1				23
24–25				4	4	3	5	4	2	1	1					24
25–26			2	2	5	5	1	5	3	2	1					26
26–27			2	1	2	4	6	12	3	1	3	1	1			36
27–28					1	7	3	7	5	5	4	4				36
28–29			1	1	1	2	4	8	6	4	5	2	1	1	1	37
29–30						1	5	5	4	4	3	1	1			24
30–31					3	2	2	4	6	1	1					19
31–32					1		1	2			1					5
32–33									1							1
33–34							1									1
Totals	3	5	18	26	35	40	38	50	32	20	19	9	3	1	1	300

FIG. 108.*— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative. Welcome*

r = 575 ± .026

* See footnote to Fig 73, page 955

Series 1257

	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	Totals
5–6						1						1
6–7			2									2
7–8	1		2	3	1		2					9
8–9		3		2	2		2					9
9–10					4	1		2				7
10–11			3	5	3	5	5	3	1		1	26
11–12				2	7	8	13	3	4			37
12–13				1	1	15	8	11	8	2		46
13–14			1	1	3	6	9	14	7	10	1	52
14–15			1	2	1	5	6	4	11	13	3	46
15–16			1			2	3	7	6	9	7	35
16–17					1	1	1	2	3	6	5	19
17–18					1	2	1	3	3		1	11
Totals	1	3	10	16	24	46	50	49	43	40	18	300

FIG. 109.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative. Sixty Day*

r = .577 ± .026

For average weight of kernels per plant correlated with average number of kernels per culm of plant (Figs. 110 to 113), the highest coefficient is .524 ± .028 for series 1200, and the lowest is .340 ± .034 for series 1219. The difference here is .184 ± .044, which is a little more than four times its probable error.

Series 1200

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	68–72	72–76	76–80	Totals
10–11		1	1																2
11–12			1	1															2
12–13			2																2
13–14			2	1			1												4
14–15	1	2	2	2		1													8
15–16			3	1															4
16–17	1		1	5	1	1	1		2										12
17–18		3	2		2		1	2				1	1						12
18–19		2	4			2	1	3		1									13
19–20		1	3	1	5	2	5	2	1	1									21
20–21			1	4	4	3	1	8	1										22
21–22			1	2	4	2	3	5	2	2		1							22
22–23		2		6	7	6	3	5	3	1	2	1	1						37
23–24			2		8	4	1	2	2	2	2								23
24–25		1			1	4	3	3	1	2	1	1	2					1	20
25–26			1		4	1	4	4	5	2	1	1	1						24
26–27	1				1	1	1	3	3	3	2		2				1		18
27–28				1	1	2	1	2		3	1	2		1	1	2			17
28–29				2			3	2	3	1	1	3			1				16
29–30					1	2		2	3	2		1	1						12
30–31								1	1	1		1	1						5
31–32										1			1		1				3
32–33			1																1
Totals	3	12	27	26	39	31	29	44	27	22	10	12	10	1	3	2	1	1	300

FIG. 110.*— *Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative. Great American*

r = .524 ± .028

* See footnote to Fig 73, page 955.

Series 1219

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	72–76	76–80	80–84	84–88	88–92	92–96	Totals
2– 3	1																								1
3– 4	2	2																							4
4– 5	1	2		1																					4
5– 6		2	2	1		1																			6
6– 7	1	3	2	4																					10
7– 8	2		3	5	3	2		1	1						1										18
8– 9		1	2	2	4	3	3	3	3	2	2			1											26
9–10		2	2	4	5	8	6	2	2	4	2	1		4	1	1									44
10–11		1	7	1	3	2	6	2	6	4	5	3	2	4	5										51
11–12		2	4	2	2	5	6	1	3	5	1	1	1	1		2		1							37
12–13			2	2		5		3	3	4	1	3	3	1	3				1				1		32
13–14			2		2	3		2	1	2			2	2	1	1				1				1	20
14–15		1	2	2		4		1	1	1		2			1		2								17
15–16	1	1	1	2	1	1			1	2	1	2			1	1									15
16–17		1				1	1						1		2			1		1					8
17–18				1			2			1															4
18–19				2			1																		3
Totals	8	18	29	29	20	35	25	15	21	25	12	12	9	13	15	5	2	2	1	2	0	0	1	1	300

FIG. 111.—*Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative. Early Champion*

r = 340 ± 034

Series 1238

	0– 4	4– 8	8– 12	12– 16	16– 20	20– 24	24– 28	28– 32	32– 36	36– 40	40– 44	44– 48	48– 52	52– 56	56– 60	60– 64	64– 68	68– 72	72– 76	76– 80	80– 84	84– 88	88– 92	92– 96	96–100	Totals
7- 8		1																								1
12–13		2																								2
15–16	2		1						1																	4
16–17		1																								1
17–18		3	2	1	1																					7
18–19	1	2	3			1					1															8
19–20	1	3	3	2		1			1																	11
20–21	1	1	3	2	2	1	3			2																15
21–22		1	1	2	1	1	1		1																	8
22–23		1	2	2	1	3	1					1														11
23–24		1	6	3	3	5			2	1	1									1						23
24–25			4	6	3		3	3	1	1	1			1			1									24
25–26	1	1	4	1	4		2	3	1	1	2	1	2	1		1		1								26
26–27		1	2	3	3	4	4	2	4	2	1		5	2			3									36
27–28			1	2	2	1	4	3	4	1	4	3	1	3	1		1	2	2			1				36
28–29	1			1		2	5	3		5	4	2	3	1	2	1	2	1	1		1			1	1	37
29–30					1	1	2	3	4	3	2		2			1	2	1	1		1					24
30–31			1	1	2	1	2	2	3	1	2		2		1				1							19
31–32				1		1	1	1				1														5
32–33										1																1
33–34					1																					1
Totals	7	18	33	27	24	22	28	20	22	18	18	8	15	8	4	3	9	5	5	1	2	1	0	1	1	300

FIG. 112.*—*Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative. Welcome*

r=.494±.029

* See footnote to Fig. 73, page 955.

Series 1257

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	72–76	76–80	Totals
5–6					1																1
6–7		1	1																		2
7–8	2	3	2		1				1												9
8–9	3	1	1	2		1						1									9
9–10		1	2		2		1			1											7
10–11	3	4	3	2	4		4		2	2		1		1							26
11–12		3	5	4	7	7	4	1	2	1			1		2						37
12–13		1	2	3	9	5	5	4	5	3	5		2		2						46
13–14		2	4	6	2	7	7	2	2	2	4	4	2	3	4				1		52
14–15	2	2	1	4	5	2	2	2	3	5	5	2	3	2	3	1	1	1			46
15–16	1			4	1	1	3	6	5	2	3		3	1	2	1				2	35
16–17	1		2			1			1	1	5	1	1		5		1				19
17–18		1		2		3	2			1						2					11
Totals	12	19	23	27	32	27	28	15	21	18	22	9	12	7	18	4	2	1	1	2	300

FIG. 113.—*Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative. Sixty Day*

$r = .415 \pm .032$

There are some slight differences observable in the coefficients here determined, which may be mentioned as possibly having some varietal significance. The highest correlation coefficient is found in series 1238 in four out of seven comparisons, and in the remaining three cases it is high. In no case is it the lowest. In three out of seven cases, series 1200 has the highest coefficient, and once it has the lowest coefficient. Series 1219 has the lowest coefficient in six out of seven cases. One would expect, then, to find in the Welcome variety of oats relatively high correlation between all characters here used in correlation studies. In the Great American variety there is relatively high correlation when average weight of kernels per plant is one of the characters considered, and relatively low when yield is correlated with weight of straw, although the coefficient is very high in the latter case. In the Early Champion variety relatively low correlations may be expected when practically all the characters here concerned are correlated, but especially when average weight of kernels is a factor. The coefficients themselves, however, are high. The Sixty Day variety seems to occupy an intermediate position as regards correlation of the characters under consideration.

The differences between the coefficients of correlation for the same characters determined for the different varieties are assembled in Table 6:

TABLE 6. SUMMARY OF DIFFERENCES IN CORRELATION COEFFICIENTS FOR THE SAME CHARACTERS IN THE FOUR VARIETIES COMPARED

Characters correlated	Difference	Difference / P. E. difference
Yield and height	030 ± 013	2 3
Yield and number of kernels	051 ± 005	10 2
Yield and number of spikelets	069 ± 006	11 5
Yield and weight of straw	126 ± 014	9 0
Yield and weight of kernels	147 ± 035	4 2
Weight of kernels and height	101 ± 035	2 9
Weight of kernels and number of kernels	184 ± 044	4 2

The largest absolute difference between the correlation coefficients for the different varieties occurs in the correlation between average weight of kernels and average number of kernels per culm, where it is .184 ± .044. The relative difference here, as indicated by the result obtained by dividing the difference by its probable error, is 4.2 times the probable error. The second largest absolute difference is when yield is correlated with average weight of kernels, the difference here being .147 ± .035, which is again 4.2 times the probable error. The third largest absolute difference is when yield is correlated with average weight of straw, the difference here being .126 ± .014, which is just nine times the probable error. The only other difference above .10 is that existing when average weight of kernels is correlated with height, which is .101 ± .035, this being 2.9 times the probable error. The difference in the correlations between yield and number of kernels is not large in absolute amount, being but .051 ± .005, but, owing to the small probable error, it amounts to 10.2 times the latter. The difference in the correlation between yield and number of spikelets is .069 ± .006, which is 11.5 times its probable error. This absolute difference is again small, but the relative difference is large because of its small probable error. The difference between the correlations of yield and height is both absolutely and relatively small, being .030 ± .013.

The greatest absolute differences, then, are seen to be found when weight of straw and average weight of kernels are correlated with other characters,

while the greatest relative differences are found when yield is correlated with weight of straw and number of kernels and of spikelets.

The coefficients here reported are usually fairly close together for the different varieties. No striking differences occur, such as exist between the results of Waldron and those of the writer. Since, however, the variety used by Waldron is not here concerned, it cannot be said that the difference in his results was not due to varietal causes. Some differences occur in these results which are evidently due to varietal causes, hence we must conclude that differences in correlation coefficients may result from the use of different varieties.

Comparison of biometrical constants determined for oat plants grown in hills and in drills

Some statistical work has been done on cereals in which the plants used were grown a fixed and uniform distance apart, the plants each being thus allowed the same amount of space in which to grow. Other work has been done with plants that were grown in rows, in which the grain was drilled in the ordinary method of seeding. The work of Roberts (1911) and of Myers (1911) on wheat was with plants grown in hills several inches apart. The work of Noll (1911) on wheat was with plants or culms that grew in drilled rows. The work of Atkinson (1912) was with wheat that was seeded broadcast in plats, the same quantity of different varieties being used. The work of Waldron (1910) on oats was with plants from drilled rows.

What differences, if any, exist in the constants determined for plants grown in these ways? In which case is there greater variability, if difference exists? In which is there greater correlation, if difference exists?

In order to test the effect of growing plants in separate hills and in drilled rows on the biometrical results, the following plantings were made:

Sixty Day selection, pure line 62–II–6–3, and Early Champion selection, pure line 137–6, were each sown in drills, fifteen grams being sown uniformly in eighteen-foot rows, the rows being one foot apart. Separate kernels of the two lines were also planted in hills three inches apart in

eighteen-foot rows, the rows again being one foot apart. All plants were harvested separately, measured, and the constants determined. The conditions may be summarized as follows:

Series	Variety	Method of sowing
1219	Early Champion	In drills
1221	Early Champion	In hills
1257	Sixty Day	In drills
1259	Sixty Day	In hills

The date of harvesting (pulling), the varieties, and the figures showing thickness of stand are:

Series	Variety	Harvested	Thickness of stand
1219	Early Champion	July 24, 1911	600 plants in 18 feet = 33.3 plants per foot
1221	Early Champion	August 4, 1911	3 inches apart in rows
1257	Sixty Day	July 24, 1911	600 plants in 18 feet = 33.3 plants per foot
1259	Sixty Day	August 4, 1911	3 inches apart in rows

The numbers of culms produced by the plants grown under the different conditions are:

Series	Method of growing	Number of culms per plant								
		1	2	3	4	5	6	7	8	9
1219	In drills	295	5	..	.	..	..	.	..	..
1221	In hills	41	52	144	39	18	4	1	1	..
1257	In drills	288	11	1	..	..		.		..
1259	In hills	37	51	103	58	39	8	1	2	1

The number of culms per plant is thus seen to be reduced practically to the minimum by growing the plants in drilled rows.

The means (M), standard deviations (σ), and coefficients of variability (C) for the plants grown from these sowings are given in Table 7:

TABLE 7. MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIABILITY, SERIES 1219, 1221, 1257, 1259.* VARIETIES IN HILLS AND IN DRILLS

	1219	1221	1257	1259
Average yield of culm per plant, in decigrams				
M. .	3 433 ± .096	7 890 ± .118	3 950 ± 102	9 087 ± .124
σ .	2 473 ± .068	3.034 ± .083	2.628 ± .072	3.186 ± .088
C.....	72 04 ± 2.82	38.45 ± 1.20	66.53 ± 2.51	35.06 ± 1.08
Average height of plant, in centimeters				
M....	55 850 ± .432	58.683 ± .290	49 566 ± .416	51.916 ± .252
σ....	11.114 ± .306	7.462 ± .205	10 703 ± .294	6.486 ± .178
C.....	19 90 ± .57	12 72 ± .36	21.59 ± 62	12.49 ± .35
Average number of kernels per culm of plant				
M....	29.293 ± .695	55 293 ± .737	28 440 ± .663	55.480 ± .700
σ....	17 867 ± 491	18 942 ± .521	17 054 ± .469	17.992 ± 495
C.....	60.99 ± 2 21	34.26 ± 1.05	59 96 ± 2 16	32.43 ± .98
Average number of spikelets per culm of plant				
M....	17.160 ± 359	31.427 ± .393	14.000 ± .330	28.260 ± .357
σ....	9.230 ± .254	10.110 ± .278	8 475 ± .233	9.190 ± .253
C.....	53.79 ± 1.86	32.17 ± .97	60.54 ± 2 19	32.52 ± .98
Average weight of straw per culm of plant, in decigrams				
M....	5.227 ± 107	10.190 ± .129	5.303 ± .116	9.423 ± .117
σ....	2.763 ± .076	3.317 ± .091	2.977 ± .082	2.997 ± .082
C.....	52.86 ± 1.81	32.55 ± .99	56.14 ± 1.97	31.81 ± 96
Average weight of kernels per plant, in milligrams				
M....	10.913 ± .115	14.080 ± .066	13.067 ± .093	16.163 ± .063
σ....	2.967 ± .082	1.684 ± .046	2.400 ± .066	1.632 ± .045
C.....	27.19 ± .80	11.96 ± .33	18.37 ± .52	10.10 ± .28

* 1219, Early Champion in drills
1221, Early Champion in hills
1257, Sixty Day in drills
1259, Sixty Day in hills

Comparing first the means for average yield of culm per plant in decigrams, it is seen that these are, respectively, 3.433 ± .096 for series 1219; 7.890 ± .118 for series 1221; 3.950 ± .102 for series 1257; and 9.087 ± .124 for series 1259. . It is thus clear that both varieties agree in having a greater mean for yield of culm when the plants are grown in hills than when grown in drills. The standard deviations are likewise greater for the plants grown in hills. There is, then, a larger yield per culm and a greater variability in yield per culm when plants are grown in hills than when they are grown in drills.

In the average height of plant in centimeters, the means are 55.850 ± .432 for series 1219; 58.683 ± .290 for series 1221; 49.566 ± .416 for series 1257; and 51.916 ± .252 for series 1259. The plants grown in hills, therefore, are on the average slightly taller than those grown in drills. As regards the standard deviations, conditions are reversed from what they were in average yield. For series 1219 the standard deviation is 11.114 ± .306, for series 1221 it is 7.462 ± .205, for series 1257 it is 10.703 ± .294, and for series 1259 it is 6.486 ± .178. It is thus seen that there is greater variability for average height in plants grown in drills than in plants grown in hills.

The means for average number of kernels per culm of plant are about twice as high in series 1221 and series 1259 as in series 1219 and series 1257, respectively. The standard deviations are slightly greater, also, for series 1221 and series 1259. These results indicate that culms grown on plants in hills produce nearly twice as many kernels as do culms grown on plants in drills, but that the variation is about the same.

The means for average number of spikelets per culm of plant are about twice as high in series 1221 and series 1259 as in series 1219 and series 1257, respectively. The standard deviations also are slightly greater in the two former series. This indicates that there are about twice as many spikelets produced on culms of plants grown in hills as on those grown in drills, but that the variation in number of spikelets on such culms is only slightly greater.

For average weight of straw per culm of plant in decigrams, the means for series 1221 and series 1259 are again nearly twice as high as for series 1219 and series 1257, respectively, and again the standard deviations are greater for the two former series. About twice as much straw per culm

is therefore produced by plants growing in hills as compared with those grown in drills, and the variability in this character is also somewhat greater for plants grown in hills.

For average weight of kernels per plant in milligrams, the means are a little greater for series 1221 and series 1259 than for series 1219 and series 1257, respectively. The standard deviations here are higher for series 1219 and series 1257 than for their corresponding series. Larger kernels are therefore produced by plants grown in hills than by plants grown in drills, but the difference is not so great as that which occurs in any other character studied, with the exception of height of plant. The variability, however, in average kernel weight is greater in plants grown in drills, this being probably due to the fact that the kernels on the isolated plants have a more uniform opportunity to develop than do those in more crowded positions.

The results obtained for both varieties dealt with are identical in character.

Regarding all characters here studied of the plants grown under these two conditions, the means are greater in every case for the plants grown in hills than for those grown in drills. It is evident that the full development allowed to plants in more isolated positions is not permitted in more crowded positions. The least difference in the means occurs in average height of plant and average weight of kernels per plant. The crowded conditions do not hinder the growth in height and the development of the kernels so much as they hinder the increase in yield, number of kernels and of spikelets, and weight of straw.

There is greater variability in average yield of culm per plant and average weight of straw per culm of plant with plants grown in hills than with those grown in drills, but much less variability in average height of plant and average weight of kernels. The variability in number of kernels and number of spikelets is slightly greater for the plants grown in hills. The standard deviation is here taken as the index of variability.

Correlations

The correlations of the two varieties as grown in hills and in drills are given in Table 8:

TABLE 8. CORRELATIONS, SERIES 1219, 1221, 1257, 1259.* VARIETIES IN HILLS AND IN DRILLS

Average yield of culm per plant, in decigrams — Average height of plant, in centimeters			
1219	r = 859 ± 010	1257	r = 875 ± .009
1221	r = 853 ± 011	1259	r = 788 ± .015
Average yield of culm per plant, in decigrams — Average number of kernels per culm of plant			
1219	r = .934 ± .005	1257	r = 965 ± 003
1221	r = 952 ± .004	1259	r = 960 ± 003
Average yield of culm per plant, in decigrams — Average number of spikelets per culm of plant			
1219	r = .916 ± .006	1257	r = 954 ± .003
1221	r = .931 ± 005	1259	r = .956 ± .003
Average yield of culm per plant, in decigrams — Average weight of straw per culm of plant, in decigrams			
1219	r = .933 ± 005	1257	r = .925 ± .006
1221	r = .856 ± 010	1259	r = .787 ± 015
Average yield of culm per plant, in decigrams — Average weight of kernels per plant, in milligrams			
1219	r = .539 ± .028	1257	r = .563 ± .027
1221	r = .493 ± .029	1259	r = .407 ± .032
Average weight of kernels per plant, in milligrams — Average height of plant, in centimeters			
1219	r = .553 ± .027	1257	r = .577 ± .026
1221	r = .325 ± .035	1259	r = .186 ± .038
Average weight of kernels per plant, in milligrams — Average number of kernels per culm of plant			
1219	r = .340 ± .034	1257	r = .415 ± .032
1221	r = .250 ± .036	1259	r = .186 ± .038

* 1219, Early Champion in drills
1221, Early Champion in hills
1257, Sixty Day in drills
1259, Sixty Day in hills

Considering first the correlations between average yield of culm per plant and average height of plant (Figs. 87, 72, 89, 114), it is seen that the coefficients for series 1219 and series 1221 differ by only .006 ± .015, which is a negligible difference. In series 1257 the coefficient is .087 ± .017 greater than in series 1259. This is more than five times its probable error, and may be of significance.

Series 1259

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	Totals
0– 1	1									1
1– 2		1				1				2
2– 3		2	2	2	1					7
3– 4		1	3	3	1	1	1			10
4– 5			1	9	3	1				14
5– 6				8	7	5				20
6– 7				6	13	3	1			23
7– 8				2	17	14				33
8– 9				1	12	17	3			33
9–10					6	17	12		1	36
10–11					1	15	10	2		28
11–12						11	18	3		32
12–13					1	4	18	8		31
13–14						2	7	6		15
14–15						1	6	2		9
15–16						1	1	2		4
16–17							2			2
Totals	1	4	6	31	62	93	79	23	1	300

FIG. 114.— *Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative*

r = .788 ± .015

For average yield of culm per plant and average number of kernels per culm of plant (Figs. 91, 74, 93, 115), the coefficients are above .934 in every case, and are so close together in the same varieties for the two methods of sowing that no comment is necessary.

For average yield of culm per plant and average number of spikelets per culm of plant (Figs. 95, 76, 97, 116), the same relative conditions exist as in the preceding case. All the coefficients are above .916, and those for the same varieties are very near each other in value.

Series 1259

F	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	72–76	76–80	80–84	84–88	88–92	92–96	96–100	Totals
0–1	1																									1
1–2				1	1																					2
2–3			2		3	2																				7
3–4						1	7	1	1																	10
4–5						1	2	9	1	1																14
5–6							1	3	7	8	1															20
6–7								1	1	10	8	1	1			1										23
7–8										2	8	11	7	4	1											34
8–9											1	5	3	14	7	3										33
9–10													4	4	16	10	1	1								36
10–11														1	3	7	9	7	1							28
11–12															3	5	5	11	4	4						32
12–13																	3	9	7	11		1				31
13–14																			2	8	3	1	1			15
14–15																		1	1	2	3	1	1			9
15–16																			1			1		1	1	4
16–17																							1		1	2
Totals	1	0	2	1	4	4	10	14	10	21	18	17	15	23	30	26	18	29	16	25	6	4	3	1	2	300

FIG. 115.—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative*

r = .960 ± .003

Series 1259

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	36–38	38–40	40–42	42–44	44–46	46–48	48–50	Totals
0– 1	1																									1
1– 2				1	1																					2
2– 3			1	1	2	3																				7
3– 4							7	3																		10
4– 5						1	3	6	3	1																14
5– 6							2	1	5	8	4															20
6– 7								1	4	7	6	3		1		1										23
7– 8										2	5	11	8	4	3											33
8– 9											1	3	3	12	8	4	2									33
9–10													3	6	14	8	4	1								36
10–11														1	1	8	9	5	3	1						28
11–12															4	3	4	8	9	4						32
12–13																		10	5	9	6	1				31
13–14																			1	5	6	2	1			15
14–15																			2	2	2	2	1			9
15–16																				1			1		2	4
16–17																							1		1	2
Totals	1	0	1	2	3	4	12	11	12	18	16	17	14	24	30	24	19	24	20	22	14	5	4	0	3	300

FIG. 116.—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative*

r = .956 ± .003

For average yield of culm per plant and average weight of straw per culm of plant (Figs. 99. 78, 101. 117), the coefficient for series 1219 is .933 ± .005. This is greater than that for series 1221 by .077 ± .011. The coefficient for series 1257 is .925 ± .006. This is greater than that for series 1259 by .138 ± .016. The first of these differences is seven times its probable error; the second is a little less than nine times its probable error.

Series 1259

	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	20-21	28-29	Totals
0- 1			1															1
1- 2	1				1													2
2- 3	2	1	2	1	1													7
3- 4			5	1	3			1										10
4- 5			4	8		1			1									14
5- 6				3	8	5	2		2									20
6- 7				5	7	6	2	2		1								23
7- 8				1	6	13	9	1		1	2							33
8- 9					2	8	11	8	1	3								33
9-10						2	12	10	6	2	2		1			1		36
10-11					1	2	1	8	6	8	2							28
11-12							1	4	6	10	8	2					1	32
12-13							1	2	4	5	11	6	2					31
13-14								1	1	3	6	2	1	1				15
14-15										1	5	3						9
15-16											1	1	2					4
16-17													1		1			2
Totals	3	1	12	19	29	37	39	37	27	34	37	14	7	1	1	1	1	300

FIG. 117.*—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative*

$r = .787 \pm .015$

* See footnote to Fig. 73, page 955.

For average yield of culm per plant correlated with average weight of kernels per plant (Figs. 103, 80, 105, 118), the coefficient for series 1219 is .539 ± .028, which is .046 ± .040 higher than that for series 1221. This difference is only a little more than the probable error. For series 1257 the coefficient is .563 ± .027, which is .156 ± .042 higher than that for series 1259. This difference is less than four times its probable error.

Series 1259

	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	Totals
0– 1			1										1
1– 2	1		1										2
2– 3				1	1		1	2		1	1		7
3– 4			1	4	1	2	1	1					10
4– 5				1	1	3	2	5	1		1		14
5– 6					1	5	5	4	2	2	1		20
6– 7			1	1		2	8	7	1	2	1		23
7– 8				1	5	2	7	12	3	1	2		33
8– 9					1	5	14	7	4	1	1		33
9–10						5	12	10	6	3			36
10–11					1	4	9	10	3		1		28
11–12						1	9	10	5	6	1		32
12–13						1	7	9	10	4			31
13–14						1		9	4	1			15
14–15								2	3	2	1	1	9
15–16							1	1		1	1		4
16–17								1		1			2
Totals	1	0	4	8	11	31	76	90	42	25	11	1	300

Fig. 118.—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative*

r = .407 ± .032

The average weight of kernels per plant correlated with average height of plant (Figs. 107, 82, 109, 119) shows a greater difference in the coefficients. For series 1219 the coefficient is .553 ± .027, and for series 1221 it is .325 ± .035. The difference is here .228 ± .044, which is about five times its probable error. For series 1257 the coefficient is .577 ± .026, and for series 1259 it is .186 ± .038, the difference here being .391 ± .046, which is eight and one half times its probable error. This difference is doubtless of significance.

Series 1259

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	Totals
9–10						1				1
10–11										0
11–12	1	1		1			1			4
12–13		1	2	2	2	1				8
13–14			1	2		7	1			11
14–15				6	4	12	6	3		31
15–16			2	5	18	28	17	5	1	76
16–17			1	11	19	24	24	11		90
17–18				1	9	11	18	3		42
18–19		1		2	6	5	10	1		25
19–20		1		1	4	4	1			11
20–21							1			1
Totals	1	4	6	31	62	93	79	23	1	300

FIG. 119.—*Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative*

$r = .186 \pm .038$

For average weight of kernels per plant correlated with average number of kernels per culm of plant (Figs. 111, 84, 113, 120), the coefficient for series 1219 is .340 ± .034, and for series 1221 it is .250 ± .036, showing a difference of .090 ± .050, which is a little less than twice its probable error. Between series 1257 and series 1259 there is a difference of .229 ± .050, which is more than four times its probable error. This difference is probably significant.

Series 1259

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	72–76	76–80	80–84	84–88	88–92	92–96	96–100	Totals
9–10					1																					1
10–11																										0
11–12	1			1					1							1										4
12–13						1	3	1		1			1	1												8
13–14						1	1	1		1			2	2	1	1			1							11
14–15							2	2	1	4	3		1	1	3	5	1	5		1		1	1			31
15–16					1		2	1	2	7	3	4	4	10	11	6	5	6	3	10					1	76
16–17					2	1		5	5	3	8	8	2	4	9	7	7	6	6	9	3	2	1	1	1	90
17–18							1	1	1	1	2	4	2	4	3	2	2	10	3	3	3					42
18–19			1					2		2	2		3		3	3	3	1	1	2		1	1			25
19–20			1			1	1	1		2		1		1		1			2							11
20–21																		1								1
Totals	1	0	2	1	4	4	10	14	10	21	18	17	15	23	30	26	18	29	16	25	6	4	3	1	2	300

FIG. 120.—*Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative*

r = .186 ± .038

The correlations obtained between the several characters considered for plants of the same pure lines grown in hills and in drills do not in the main differ radically from each other for the two methods of planting. There are, however, some rather large differences in a few cases. The differences, as given in Table 9, range from .002 ± .004 to .391 ± .046. The latter is of considerable value and is doubtless significant. Five out of fourteen correlations have differences amounting to more than .10, and of these four are found in the Sixty Day variety. Only three have differences amounting

TABLE 9. SUMMARY OF DIFFERENCES IN CORRELATION COEFFICIENTS FOR THE SAME CHARACTERS IN THE SAME PURE LINES GROWN IN HILLS AND IN DRILLS

Characters correlated	Extreme difference		$\frac{\text{Difference}}{\text{P. E. difference}}$	
	1219 and 1221	1257 and 1259	1219 and 1221	1257 and 1259
Yield and height	006 ± .015	087 ± 017	0 4	5 1
Yield and number of kernels	018 ± 006	005 ± 004	3 0	1.2
Yield and number of spikelets	.015 ± 008	002 ± 004	1 9	0 5
Yield and weight of straw	.077 ± .011	.138 ± .016	7 0	8 6
Yield and weight of kernels	046 ± .040	.156 ± .042	1.1	3.7
Weight of kernels and height	228 ± .044	.391 ± .046	5.2	8.5
Weight of kernels and number of kernels	.090 ± .050	.229 ± .050	1 8	4.6

to more than about five times their probable errors, and two of these are in Sixty Day, these two being when yield is correlated with weight of straw and when weight of kernels is correlated with average height; the third case is when average yield is correlated with weight of straw in Early Champion.

Whenever great differences in the coefficients occur, those for the plants grown in hills are always the smaller in amount. It seems, then, that correlation is reduced in amount by allowing more room for the growth and development of plants. Correlation may be considerably modified by the method of growing plants.

The differences produced in the correlation coefficients by differences in the growing conditions may amount to more than any varietal differences that have been observed in the course of this work. By reference to Table 6 it is seen that the range of the differences between the correlation coefficients of different varieties is from .030 to .184, while by reference to Table 9 it is seen that the range of the differences between the correlation coefficients of plants of the same variety grown in drills and in hills is from .002 to .391. Thus the constants obtained by different investigators are comparable only in so far as the conditions of growth are comparable.

Effect of different degrees of crowding on biometrical constants of oats

Are variation and correlation of oats modified by different degrees of crowding in the row? In other words, do oat plants develop in the same way when they are crowded together as thickly as they can stand, as when they are less crowded?

In order to answer these questions, plantings of two pure lines of oats were made in eighteen-foot rows, side by side, on as uniform soil as could be found. One variety was Sixty Day, pure line 62–II–19–2, which had been grown twice from an individual plant and had been propagated for several years by the Department of Plant-Breeding at Cornell University. The other variety was originated by crossing Sixty Day and Probsteier, this having been done some eight or ten years previously. This line, known as 50a1–18–2, was twice selected from the progeny of the cross, and is very uniform. It also has been grown for several years by the Department of Plant-Breeding.

Three different rates of sowings of these lines were made. Lots of 386 kernels and 1000 kernels each were counted out and weighed. Then in each line 40.45 grams was weighed, and the kernels in these weighings were counted. The number of kernels and the weight of the same, for each variety, sown in each eighteen-foot row, are given in the following table, together with the series numbers by which the different sowings are to be known:

TABLE 10. NUMBER AND WEIGHT OF KERNELS SOWN IN EACH EIGHTEEN-FOOT ROW, FOR EACH SERIES USED

Series	Variety	Pure line	Number of kernels sown in 18-foot row	Weight of kernels sown in 18-foot row (grams)
68	Sixty Day	62-II-19-2	386	5.56
102	Sixty Day	62-II-19-2	1,000	15.22
118	Sixty Day	62-II-19-2	2,870	40.45
63	Sixty Day × Probsteier hybrid	50a1-18-2	386	8.11
100	Sixty Day × Probsteier hybrid	50a1-18-2	1,000	20.26
122	Sixty Day × Probsteier hybrid	50a1-18-2	1,925	40.45

These oats were sown on May 12, 1911. The date of pulling and the number of plants harvested in each series from the eighteen-foot rows are given in the following table:

TABLE 11. DATE OF PULLING AND NUMBER OF PLANTS HARVESTED IN EACH ROW, FOR EACH SERIES USED

Series	Date of pulling	Number of plants in 18-foot row
68	July 18, 1911	369
102	July 18, 1911	720
118	July 18, 1911	2,000
63	July 21, 1911	328
100	July 21, 1911	800
122	July 21, 1911	1,500

It is seen that not all the kernels that were planted produced mature plants, yet enough plants matured to show radical differences in the rate of crowding.

The numbers of culms per plant for the 300 plants used for biometrical study of each of these series of oats are given in the following table:

TABLE 12 NUMBER OF CULMS PER PLANT FOR EACH SERIES

Series	Number of culms per plant				Average number of culms per plant
	1	2	3	4	
68	156	102	38	4	1.633
102	275	24	1		1 087
118	300				1
63*.	147	71	19	1	1.471
100.	300				1
122.	300				1

*In this series 238 plants were used

There is very little stooling when 700 plants of these varieties are grown in eighteen-foot rows, and none at all when as many as 1500 are so grown.

The means (M), standard deviations (σ), and coefficients of variability (C) for ten characters of these two lines of oats, sown at these different rates, are given in Tables 13 and 14. In these tables the figures for the least crowded series are given in the left column, those for the most crowded in the right column, and the intermediate in the middle. Line 50a1–18–2 is reported in Table 13, and line 62–II–19–2 in Table 14. These lines will be referred to hereinafter as lines 50 and 62.

TABLE 13. MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIABILITY, SERIES 63, 100, 122. DEGREES OF CROWDING. PURE LINE 50a1–18–2

	63	100	122
Average yield of culm per plant, in decigrams			
M	6.063 ± 108	2 630 ± 065	1 917 ± .047
σ	2.469 ± 076	1 665 ± .046	1.215 ± .033
C	40 72 ± 1.45	63.31 ± 2.34	63.38 ± 2.34
Average height of plant, in centimeters			
M	71 785 ± .441	55.850 ± .448	54.983 ± .426
σ	10.100 ± .312	11 526 ± .317	10.950 ± 301
C	14.07 ± .44	20.64 ± 59	19 92 ± .57

TABLE 13. MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIABILITY (*continued*)

Average length of head per plant, in centimeters

	63	100	122
M	12.101 ± .097	8.730 ± .084	7.290 ± .079
σ	2.226 ± .069	2.161 ± .059	2.039 ± .056
C	18.40 ± .59	24.75 ± .72	27.97 ± .83

Average weight of kernels per plant, in milligrams

	63	100	122
M	17.882 ± .137	14.943 ± .123	15.527 ± .140
σ	3.134 ± .097	3.154 ± .087	3.603 ± .099
C	17.53 ± .56	21.11 ± .61	23.20 ± .67

Average number of kernels per culm of plant

	63	100	122
M	32.941 ± .516	16.267 ± .357	11.200 ± .255
σ	11.803 ± .365	9.184 ± .253	6.544 ± .180
C	35.83 ± 1.24	56.46 ± 1.99	58.43 ± 2.08

Diameter of straw, in decimillimeters

	63	100	122
M	26.546 ± .191	16.600 ± .195	14.240 ± .166
σ	4.377 ± .135	5.012 ± .138	4.263 ± .117
C	16.49 ± .52	30.19 ± .90	29.94 ± .89

Average weight of straw per culm of plant, in decigrams

	63	100	122
M	7.739 ± .114	4.143 ± .086	2.900 ± .060
σ	2.600 ± .080	2.213 ± .061	1.553 ± .043
C	33.60 ± 1.15	53.42 ± 1.84	53.55 ± 1.85

Average number of spikelets per culm of plant

	63	100	122
M	15.815 ± .270	7.560 ± .164	5.240 ± .111
σ	6.176 ± .191	4.228 ± .116	2.856 ± .079
C	39.05 ± 1.38	55.93 ± 1.96	54.50 ± 1.89

Average number of kernels per spikelet of plant

	63	100	122
M	2.073 ± .011	2.093 ± .012	2.005 ± .012
σ	.253 ± .008	.299 ± .008	.306 ± .008
C	12.20 ± .38	14.29 ± .40	15.26 ± .43

TABLE 13. MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIABILITY (*concluded*)

	Breaking strength of straw, in grams 63	100	122
M	226 638 ± 3 704	105 666 ± 1.860	74 734 ± 1 575
σ	84 766 ± 2 619	47 818 ± 1.315	40 500 ± 1 114
C	37 40 ± 1 31	45.25 ± 1.48	54 19 ± 1 88

TABLE 14. MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIABILITY, SERIES 68, 102, 118. DEGREES OF CROWDING. PURE LINE 62-II-19-2

	Average yield of culm per plant, in decigrams 68	102	118
M	4.890 ± .081	2.503 ± .066	1.287 ± .039
σ	2 076 ± .057	1.708 ± .047	1.000 ± .027
C	42 45 ± 1.36	68.24 ± 2.61	77.70 ± 3.17
	Average height of plant, in centimeters 68	102	118
M	64.583 ± .420	51.750 ± .507	48.000 ± .429
σ	10 805 ± .297	13.026 ± .358	11 034 ± .303
C	16.73 ± .47	25.17 ± .73	22.99 ± .66
	Average length of head per plant, in centimeters 68	102	118
M	11.123 ± .075	8.283 ± .091	6.257 ± .077
σ	1.933 ± .053	2.327 ± .064	1.976 ± 054
C	17.38 ± .49	28.09 ± .83	31.58 ± .95
	Average weight of kernels per plant, in milligrams 68	102	118
M	13.197 ± .074	10 917 ± .103	10.490 ± .101
σ	1.895 ± .052	2.655 ± .073	2.592 ± 071
C	14.36 ± .40	24.32 ± .71	24.71 ± .72
	Average number of kernels per culm of plant 68	102	118
M	36 013 ± .528	20.787 ± .507	10.453 ± .298
σ	13.586 ± .374	13.026 ± .358	7.660 ± 211
C	37 73 ± 1.18	62.66 ± 2.30	73.28 ± 2.90
	Diameter of straw, in decimillimeters 68	102	118
M	23.907 ± .181	17.760 ± .210	12.520 ± .171
σ	4.648 ± .128	5.405 ± .149	4.386 ± .121
C	19.44 ± .55	30.43 ± .91	35.03 ± 1.08

TABLE 14. MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIABILITY (*concluded*)

	68	102	118
Average weight of straw per culm of plant, in decigrams			
M	5 963 ± 084	3 767 ± 087	2.103 ± 052
σ	2 167 ± .060	2.243 ± .062	1.341 ± .037
C	36.34 ± 1 12	59.54 ± 2.14	63.77 ± 2 36
Average number of spikelets per culm of plant			
M	17 027 ± .267	9.227 ± 215	4.707 ± 118
σ	6.857 ± .189	5.523 ± .152	3.023 ± .083
C	40 27 ± 1.27	59.86 ± 2.16	64.22 ± 2.39
Average number of kernels per spikelet of plant			
M	2.013 ± 012	2 135 ± 015	2.046 ± .012
σ	.311 ± 009	379 ± .010	.312 ± 009
C	15 45 ± .43	17.75 ± 50	15.25 ± 43
Breaking strength of straw, in grams			
M	209 346 ± 3 100	84 534 ± 1.985	58 400 ± 1.475
σ	79 696 ± 2 192	51 036 ± 1.403	37.930 ± 1.043
C	38 07 ± 1 19	60.37 ± 2.18	64 95 ± 2.43

Considering first the average yield of culm per plant in decigrams, it is seen in Table 13 that the mean for series 63 is 6.063 ± .108, for series 100 it is 2.630 ± .065, and for series 122 it is 1.917 ± .047. It is evident that the yield per culm averages higher for plants grown in the less crowded conditions. Without repeating here the means for the other line, the same results are seen to hold in this. As to variability, considering the standard deviation to be in such cases the best index, it is clear that the variability in yield of culm per plant is greatest in the plants grown under the least crowded conditions. The standard deviations for series 63, 100, and 122, are, respectively, 2.469 ± .076, 1.665 ± .046, and 1.215 ± .033. The other line exhibits about the same decrease in standard deviations from the least to the most crowded condition.

It will probably be well to take up separately the remaining characters considered, but without repeating in the text the constants recorded in the tables unless some unusual circumstance exists. Reference can be made to the tables for the constants on which conclusions are based.

There is a decrease in average height of plant in centimeters from the least to the most crowded conditions; the extreme differences being 16.802 centimeters in one line, and 16.583 centimeters in the other. As to variability, however, the plants growing under the least crowded conditions show the least variation, while those in intermediate conditions of crowding show the greatest variation. This is true for both lines.

The means for average length of head per plant in centimeters decrease as crowding increases. In line 50 the variability decreases in like manner, but the differences are slight. In line 62 the variability decreases in the same order as does that for height.

For average weight of kernels per plant in milligrams, the means decrease in regular order from the least to the most crowded condition in line 62, but the extreme difference is but 2.707 ± .125 milligrams. In line 50 the greatest weight occurs in series 63, the second greatest in series 122, and the least in series 100, the intermediate condition of crowding. The extreme difference here is 2.939 ± .184 milligrams. Variability is least in both lines in the least crowded conditions, but the differences are not great.

The average number of kernels per culm of plant decreases markedly as crowding increases; the extreme differences being 21.741 ± .576 for line 50, and 25.560 ± .606 for line 62. The variability likewise decreases as the plants have less room.

The average number of spikelets per culm of plant should be considered here, since it is so closely related to the number of kernels. The same conditions exist for the two characters. The extreme differences in the means for number of spikelets are 10.575 ± .292 for line 50, and 12.320 ± .292 for line 62, and the variability is also less as more crowded conditions prevail.

The average number of kernels per spikelet of plant should now be considered. The differences here are small, but in both lines the mean is highest when conditions of crowding are intermediate; it is lowest when crowding is greatest in line 50, and at the other extreme in line 62. Variability increases directly with crowding in line 50, but in line 62 the plants in the intermediate condition of crowding have the greatest variability, while the two extremes are practically the same.

Three lots of data have been taken on the straw: the diameter, in decimillimeters; the average weight of straw per culm of plant, in deci-

grams; and the breaking strength, in grams. For plants with more than one culm the diameter and the breaking strength were determined for the principal culm, according to methods described previously. The means for all three of these characters are seen to decrease markedly as the degree of crowding increases. The variability decreases for weight in line 50, and for breaking strength in both lines, with decrease in amount of room allowed to the plants. In line 62, however, the greatest variability in weight of straw occurs in series 102, where crowding is intermediate, but the least variability is again where the greatest degree of crowding exists. In diameter of straw the variability is greatest in both lines where the intermediate degree of crowding exists, but is least where the crowding is greatest.

Oat plants grown in very crowded positions produce but one culm to a plant, but as more room is given more than one culm are produced by many plants. Tillering ceases in these varieties when the rate of stand is somewhere about forty to forty-five plants to a foot. The development of the plants in less crowded conditions is greater than in more crowded conditions, as is evidenced by the means for yield, height, length of head, weight, diameter, and breaking strength of straw, number of spikelets per culm, and number of kernels per culm. The kernels also average heaviest when crowding is least, but there is not much difference in weight for conditions of crowding such as exist in series 100, 122, 102, and 118. The numbers of kernels produced by the spikelets do not differ greatly for the different rates of seeding; the number produced on the plants growing under medium conditions of crowding, however, is slightly the largest.

Variability, as indicated by the standard deviation, decreases in both lines with decrease in the mean in yield, number of kernels per culm, number of spikelets per culm, and breaking strength of straw. In both lines the variability for height of plant and diameter of straw is greatest for the medium thick stand. For height the least variability occurs where the most room per plant is allowed, but for diameter of straw the least variability occurs when the crowding is greatest. In line 50, variability increases with crowding for weight of kernels per plant and for number of kernels per spikelet, and decreases for weight of straw and for length of head. In line 62, variability is greatest in the medium thick stand for length of head, weight of kernels, number of kernels per spikelet, and weight of

straw, and least in the least crowded condition for the first three of these characters; for weight of straw it is least in the most crowded condition.

Correlations

The correlations that exist in the two lines under consideration sown at the different rates are given in Tables 15 and 16. Thirteen correlation coefficients for each series have been determined, and these are given

TABLE 15. CORRELATIONS, SERIES 63, 100, 122 DEGREES OF CROWDING. PURE LINE 50a1-18-2

Average yield of culm per plant, in decigrams — Average height of plant, in centimeters	63..... r = 811 ± .015	100 r = 881 ± 009	122 r = 865 ± .010
Average yield of culm per plant, in decigrams — Average length of head per plant, in centimeters	63..... r = .774 ± 018	100 . r = .847 ± 011	122.. . r = 849 ± .011
Average yield of culm per plant, in decigrams — Average number of kernels per culm of plant	63..... r = 906 ± .008	100 ... r = .930 ± 005	122 r = 908 ± .007
Average yield of culm per plant, in decigrams — Average number of spikelets per culm of plant	63..... r = .845 ± 012	100 . . r = .885 ± 008	122 r = .851 ± 011
Average yield of culm per plant, in decigrams — Average weight of kernels per plant, in milligrams	63.. .. r = 492 ± .033	100 . . r = .585 ± 026	122 .. r = .652 ± .022
Average yield of culm per plant, in decigrams — Average number of kernels per spikelet of plant	63... r = — 025 ± .044	100. . r = 404 ± 033	122 r = .489 ± .030
Average yield of culm per plant, in decigrams — Diameter of straw, in decimillimeters	63..... r = .765 ± .018	100.. . r = .882 ± 009	122.... r = .866 ± .010
Average yield of culm per plant, in decigrams — Breaking strength of straw, in grams	63. .. r = .673 ± .024	100.... r = .896 ± .008	122.... r = .870 ± .009
Average yield of culm per plant, in decigrams — Average weight of straw per culm of plant, in decigrams	63..... r = .919 ± .007	100.... r = .941 ± 004	122.... r = .901 ± .007
Diameter of straw, in decimillimeters — Breaking strength of straw, in grams	63. .. r = .820 ± .014	100.... r = .852 ± .011	122.... r = .913 ± .006
Average weight of kernels per plant, in milligrams — Average number of kernels per culm of plant	63..... r = .133 ± .043	100.... r = .363 ± .034	122.... r = .466 ± 030

TABLE 15. CORRELATIONS, SERIES 63, 100, 122 DEGREES OF CROWDING (*concluded*)

Average weight of kernels per plant in milligrams — Average height of plant, in centimeters

63 .	r = 380 ± 037	100	r = 651 ± 022	122	r = 718 ± 019

Average weight of kernels per plant, in milligrams — Average length of head per plant, in centimeters

63 .	r = 081 ± 043	100 .	r = 408 ± 032	122	r = 535 ± 028

TABLE 16. CORRELATIONS, SERIES 68, 102, 118. DEGREES OF CROWDING PURE LINE 62-II-19-2

Average yield of culm per plant, in decigrams — Average height of plant, in centimeters

68. .	r = 836 ± 012	102	r = 863 ± 010	118	r = 801 ± 014

Average yield of culm per plant, in decigrams — Average length of head per plant, in centimeters

68 . .	r = 811 ± 013	102	r = 835 ± 012	118	r = 800 ± .014

Average yield of culm per plant, in decigrams — Average number of kernels per culm of plant

68 . . .	r = 942 ± 004	102	r = 954 ± 003	118	r = 928 ± .005

Average yield of culm per plant, in decigrams — Average number of spikelets per culm of plant

68. . . .	r = .900 ± 007	102	. r ± 913 ± 006	118	r = 892 ± 008

Average yield of culm per plant, in decigrams — Average weight of kernels per plant, in milligrams

68. . .	r = 525 ± 028	102 . .	r = 583 ± 026	118	r = 568 ± 026

Average yield of culm per plant, in decigrams — Average number of kernels per spikelet of plant

68 .	r = 060 ± 039	102 .	r = 474 ± 030	118 .	r = 621 ± .024

Average yield of culm per plant, in decigrams — Diameter of straw, in decimillimeters

68. . . .	r = 785 ± 015	102	r = .878 ± 009	118 .	r = 871 ± 009

Average yield of culm per plant, in decigrams — Breaking strength of straw, in grams

68.	r = .701 ± 020	102. . . .	r ± 863 ± 010	118 . .	r = 883 ± .009

Average yield of culm per plant, in decigrams — Average weight of straw per culm of plant, in decigrams

68. . .	r = 884 ± 008	102 .	r = 944 ± 004	118	r = 888 ± .008

Diameter of straw, in decimillimeters — Breaking strength of straw, in grams

68. . . .	r = .871 ± 009	102. . . .	r = 960 ± .003	118 .	r = .899 ± 007

TABLE 16. CORRELATIONS SERIES 68, 102, 118 DEGREES OF CROWDING (*concluded*)

Average weight of kernels per plant, in milligrams — Average number of kernels per culm of plant		
68 r = 288 ± 036	102 . r = 471 ± 030	118 ... r = .487 ± 030
Average weight of kernels per plant, in milligrams — Average height of plant, in centimeters		
68 r = 450 ± 031	102 r = 733 ± 018	118 . . r = 714 ± .019
Average weight of kernels per plant, in milligrams — Average length of head per plant, in centimeters		
68. r = 265 ± 036	102.. r = 535 ± 028	118.... r = .606 ± .025

immediately beneath the characters correlated. Those for the least crowded condition are in the first column at the left, those for the most crowded condition are in the column at the right.

The average yield of culm per plant has been correlated with nine different characters. Taking up for consideration the correlation between this character and average height of plant (Figs. 121 to 126), it is seen that the highest correlation for line 50 is in series 100, where it is .881 ± .009; and for line 62 in series 102, where it is .863 ± .010. These are

Series 63

	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	Totals
1– 2	1	1	5	3	3							13
2– 3			3	4	2	2						11
3– 4	1		2	7	10	6	2	1				29
4– 5				2	4	13	5	2				26
5– 6			1	2	3	14	14	5	1			40
6– 7					3	4	17	12	8			44
7– 8						1	5	10	3	5		24
8– 9						1	2	6	6	3		18
9–10							1	3	7	4	2	17
10–11							2	1	2	3	1	9
11–12										3	2	5
12–13								1		1		2
Totals	2	1	11	18	25	41	48	41	27	19	5	238

FIG. 121.— *Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative*
r = .811 ± .015

Series 100

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	Totals
0–1	1	10	17	15	3								46
1–2		2	5	6	29	30	5						77
2–3					1	17	29	28	1				76
3–4					1	1	4	20	19				45
4–5							1	4	13	6			24
5–6								2	3	11	2		18
6–7									2	5	3	1	11
7–8											1		1
8–9											1	1	2
Totals	1	12	22	21	34	48	39	54	38	22	7	2	300

FIG. 122.— *Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative*

$r = .881 \pm .009$

$.070 \pm .017$ and $.062 \pm .017$ higher than the lowest coefficients in their respective lines. Each of these differences is about four times its probable error and they are not highly significant. The correlations are highest in both lines for plants grown in intermediate conditions of crowding

Series 122

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	Totals
0–1	1	10	25	19	19	4						78
1–2	1				20	40	28	6	1			96
2–3						3	22	29	16	2		72
3–4								11	22	4		37
4–5									5	5	2	12
5–6										2	2	4
6–7											1	1
Totals	2	10	25	19	39	47	50	46	44	13	5	300

FIG. 123.—*Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative*

$r = .865 \pm .010$

Series 68

	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	Totals
0– 1	2	2	3											7
1– 2		2	3	7	4	4	1							21
2– 3			2	4	8	10	1	1						26
3– 4				2	8	24	13	5	1					53
4– 5					1	11	18	17	6	2				55
5– 6						2	12	12	10	4	1	1		42
6– 7							6	16	10	8	1			41
7– 8								7	6	14	10			37
8– 9								2	2	3	2	3		12
9–10								1	1		2	1	1	6
Totals	2	4	8	13	21	51	51	61	36	31	16	5	1	300

FIG. 124.— *Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative*
r = .836 ± .012

and lowest, in one case for those in the least crowded condition, and in the other case for those in the most crowded condition. This would give a slight indication that yield increases in its correlation with height as crowding increases up to a certain point, beyond which there is a gradual decrease in correlation.

Series 102

	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	Totals
0–1	1	2	6	13	12	19	10								63
1–2						3	19	27	23	6					78
2–3								6	30	17	6				59
3–4									4	11	18	6	1		40
4–5									1	4	9	13	5		32
5–6											2	7	2	2	13
6–7											1	5	6	2	14
7–8															0
8–9													1		1
Totals	1	2	6	13	12	22	29	33	58	38	36	31	15	4	300

FIG. 125.— *Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative*
r = .863 ± .010

Series 118

	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	Totals
0–1	4	11	23	34	46	26	9						153
1–2				1	3	21	29	27	4	1			86
2–3					1	1	6	12	15	5			40
3–4								1	7	5	2		15
4–5									1	2	1	1	5
5–6											1		1
Totals	4	11	23	35	50	48	44	40	27	13	4	1	300

FIG. 126.—*Correlation between average yield of culm per plant, in decigrams, subject; and average height of plant, in centimeters, relative*
r = .801 ± .014

When average yield of culm per plant is correlated with average length of head per plant (Figs. 127 to 132), the coefficients are not graduated so uniformly in the two lines. The greatest correlation in line 50 occurs in series 122, being here .849 ± .011. This is for the most crowded

Series 63

	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	Totals
1–2	3	5	2	2	1							13
2–3	1	1	2	4		2	1					11
3–4	1		7	9	4	7	1					29
4–5				1	5	10	8	2				26
5–6			2	1	6	13	7	8	2	1		40
6–7			1	3	4	4	14	11	6	1		44
7–8					1	2	2	10	8	1		24
8–9						1	6	4	2	5		18
9–10							2	8	2	4	1	17
10–11								2	3	4		9
11–12							1		1	3		5
12–13											2	2
Totals	5	6	14	20	21	39	42	45	24	19	3	238

FIG. 127.—*Correlation between average yield of culm per plant, in decigrams, subject; and average length of head per plant, in centimeters, relative*
r = .774 ± .018

Series 100

	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	Totals
0–1	2	11	15	11	7								46
1–2			3	21	23	21	9						77
2–3				2	10	35	21	8					76
3–4						9	17	11	8				45
4–5						1	5	4	8	3	2	1	24
5–6							2	3	6	7			18
6–7								1	3	3	2	2	11
7–8										1			1
8–9									1		1		2
Totals	2	11	18	34	40	66	54	27	26	14	5	3	300

FIG. 128.—*Correlation between average yield of culm per plant, in decigrams, subject; and average length of head per plant, in centimeters, relative*

r = .847 ± .011

condition, and the coefficients become lower with less crowding, the lowest coefficient being .774 ± .018, or .075 ± .021 less than the highest. This difference is more than three times its probable error, and probably is not significant. In line 62 the correlation is greatest for the medium

Series 122

	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	Totals
0–1	2	15	27	27	7						78
1–2				15	31	38	9	3			96
2–3					3	20	34	10	4	1	72
3–4						3	9	13	8	4	37
4–5								3	4	5	12
5–6									3	1	4
6–7								1			1
Totals	2	15	27	42	41	61	52	30	19	11	300

FIG. 129.—*Correlation between average yield of culm per plant, in decigrams, subject; and average length of head per plant, in centimeters, relative*

r = .849 ± .011

Series 68

	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	Totals
0–1	4	2	1									7
1–2		3	7	4	7							21
2–3			4	4	12	5	1					26
3–4			1	6	16	16	10	2			2	53
4–5				1	8	15	24	5	2			55
5–6					1	7	18	14	1	1		42
6–7						2	10	18	10	1		41
7–8							7	12	15	3		37
8–9							1	4	4	2	1	12
9–10								1	2	3		6
Totals	4	5	13	15	44	45	71	56	34	10	3	300

FIG. 130.— *Correlation between average yield of culm per plant, in decigrams, subject; and average length of head per plant, in centimeters, relative*

r = .811 ± .013

condition of crowding and least for the most crowded condition, but the extreme difference is only .035 ± .018. Only slight significance can be attached to the differences in correlation in these two lines between yield and length of head, therefore definite conclusions cannot be drawn.

Series 102

	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	Totals
0–1	5	6	21	15	12	4							63
1–2				5	26	26	15	6					78
2–3					1	4	23	24	6			1	59
3–4							5	12	17	6			40
4–5							2	10	10	8	2		32
5–6								2	3	7	1		13
6–7									4	7	3		14
7–8													0
8–9											1		1
Totals	5	6	21	20	39	34	45	54	40	28	7	1	300

FIG. 131.—*Correlation between average yield of culm per plant, in decigrams, subject; and average length of head per plant, in centimeters, relative*

r = .835 ± .012

Series 118

	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	Totals
0–1	2	14	31	27	51	22	6					153
1–2					9	33	38	6				86
2–3						1	10	18	9	2		40
3–4							1	4	6	4		15
4–5									5			5
5–6											1	1
Totals	2	14	31	27	60	56	55	28	20	6	1	300

FIG. 132.— *Correlation between average yield of culm per plant, in decigrams, subject; and average length of head per plant, in centimeters, relative*

r = .800 ± .014

When the correlation between average yield of culm per plant and average number of kernels per culm of plant (Figs. 133 to 138) is considered, the differences in the correlations are so small in each line as to be of little or no significance. There is a slightly greater correlation in each line,

Series 63

	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	Totals
1– 2	7	5	1														13
2– 3	1	6	2	1	1												11
3– 4		3	8	12	5	1											29
4– 5				4	10	8	4										26
5– 6				4	10	9	13	4									40
6– 7					5	9	10	11	6	2	1						44
7– 8					1	1	3	5	11	2	1						24
8– 9							2	1	4	6	3	2					18
9–10								2	3	2	8	1		1			17
10–11										4	2	3					9
11–12										1	1	2				1	5
12–13													2				2
Totals	8	14	11	21	32	28	32	23	24	17	16	8	2	1	0	1	238

FIG. 133.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative*

r = .906 ± .008

Series 100

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	Totals
0–1	5	37	4									46
1–2		17	45	15								77
2–3			9	39	23	3	2					76
3–4				5	12	19	8	1				45
4–5				1		5	6	11	1			24
5–6							3	5	5	5		18
6–7							1	2	3	3	2	11
7–8										1		1
8–9										1	1	2
Totals	5	54	58	60	35	27	20	19	9	10	3	300

FIG. 134.—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative*

r = .930 ± .005

however, for the medium condition of crowding. The smallest coefficient is .906 ± .008, for series 63. The extreme difference of the results in line 50 is .024 ± .009, which is less than three times its probable error. In

Series 122

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	Totals
0–1	34	44							78
1–2		35	50	10	1				96
2–3			15	42	13	2			72
3–4				8	14	12	3		37
4–5						3	7	2	12
5–6							4		4
6–7							1		1
Totals	34	79	65	60	28	17	15	2	300

FIG. 135.—*Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative*

r = .908 ± .007

Series 68

	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	Totals
0– 1	5	2															7
1– 2		6	12	2	1												21
2– 3			2	8	10	5	1										26
3– 4				3	8	19	18	5									53
4– 5						4	13	15	16	4	3						55
5– 6								6	14	14	6	2					42
6– 7									1	11	16	8	5				41
7– 8										3	8	8	8	5	5		37
8– 9											1		6	3	2		12
9–10													1	1	3	1	6
Totals	5	8	14	13	19	28	32	26	31	32	34	18	20	9	10	1	300

FIG. 136.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative*
r = .942 ± 004

line 62 it is .026 ± .006, or about four times its probable error. Degrees of crowding, then, have little effect on the correlation between yield and number of kernels per culm.

Series 102

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	Totals
0–1	17	30	16													63
1–2		2	29	33	11	2	1									78
2–3				5	19	25	10									59
3–4						3	12	14	8	3						40
4–5						1	1	6	9	10	5					32
5–6										1	5	5	2			13
6–7										1	4	3	2	3	1	14
7–8																0
8–9															1	1
Totals	17	32	45	38	30	31	24	20	17	15	14	8	4	3	2	300

FIG. 137.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative*
r = .954 ± .003

Series 118

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	Totals
0–1	52	86	15								153
1–2		4	53	26	3						86
2–3			1	5	16	13	4	1			40
3–4					1	2	4	7	1		15
4–5								3	2		5
5–6										1	1
Totals	52	90	69	31	20	15	8	11	3	1	300

FIG. 138.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per culm of plant, relative*

$r = .928 \pm .005$

The correlations between average yield of culm per plant and average number of spikelets per culm of plant (Figs. 139 to 144) are again so nearly the same in amount that no significance may be placed on the difference. In line 50 the extreme difference is .040 ± .014; in line 62 it is .021 ± .010.

Series 63

	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	Totals
1–2	1	7	4	1														13
2–3	1	2	4	3			1											11
3–4			8	8	8	3	2											29
4–5				3	1	7	11	4										26
5–6			1		7	6	9	10	6	1								40
6–7				1	7	3	5	12	8	4	3		1					44
7–8					1	1	3	3	6	4	5	1						24
8–9						1	1	2	1	4	3	3	3					18
9–10							2	1	1	4	3	4	1		1			17
10–11										1	3	2	3					9
11–12											2	1	1				1	5
12–13														1		1		2
Totals	2	9	17	16	24	21	34	32	22	18	19	11	9	1	1	1	1	238

FIG. 139.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative*

$r = .845 \pm .012$

Series 100

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	Totals
0–1	5	34	7										46
1–2		20	42	15									77
2–3			25	30	15	4	2						76
3–4			3	13	12	11	6						45
4–5				2	2	5	6	6	3				24
5–6					1		6	7	3	1			18
6–7							4	2	1	4			11
7–8									1				1
8–9								1				1	2
Totals	5	54	77	60	30	20	24	16	8	5	0	1	300

FIG. 140.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative*

r = .885 ± .008

The difference in each case amounts to less than three times its probable error. Degrees of crowding, then, have little effect on the correlation between yield and number of spikelets.

Series 122

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	Totals
0–1	29	48	1						78
1–2		34	51	11					96
2–3		1	34	26	11				72
3–4			5	11	11	7	3		37
4–5					2	7	2	1	12
5–6					2	1	1		4
6–7						1			1
Totals	29	83	91	48	26	16	6	1	300

FIG. 141.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative*

r = .851 ± .011

Series 68

	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	Totals
0–1	4	3															7
1–2		9	8	4													21
2–3			7	6	7	4	2										26
3–4			5	5	14	12	11	6									53
4–5				2	1	9	20	7	11	2	3						55
5–6						2	2	9	11	12	5				1		42
6–7							1	2	2	14	11	5	5	1			41
7–8								1	3	6	6	11	2	7	1		37
8–9										1	1	1	4	2	3		12
9–10										1		1			3	1	6
Totals	4	12	20	17	22	27	36	25	27	36	26	18	11	10	8	1	300

FIG. 142.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative*

r = .900 ± .007

Series 102

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	Totals
0–1	14	32	16	1											63
1–2		6	36	24	9	2	1								78
2–3			4	11	26	12	5	1							59
3–4					7	2	14	14	3						40
4–5					2	4	5	9	9	2	1				32
5–6							1	1	4	6		1			13
6–7								2	2	4	2		2	2	14
7–8															0
8–9													1		1
Totals	14	38	56	36	44	20	26	27	18	12	3	1	3	2	300

FIG. 143.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative*

r = .913 ± .006

eries 118

	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	Totals
0–1	50	89	14							153
1–2		7	57	21	1					86
2–3			2	17	16	5				40
3–4			1	2	4	3	4	1		15
4–5						2	2	1		5
5–6									1	1
Totals	50	96	74	40	21	10	6	2	1	300

FIG. 144.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of spikelets per culm of plant, relative*

r = .892 ± .008

In the correlation between average yield of culm per plant and average reight of kernels per plant (Figs. 145 to 150), there is in line 50 a graduated ıcrease with increased crowding. For series 63 the coefficient is .492 ±)33, while for series 122 it is .652 ± .022 — an extreme difference of 160 ± .040, which, however, amounts to but four times its probable

eries 63

	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	24–25	25–26	26–27	Totals
1– 2	1		2	1	2	3	2	2											13
2– 3	1			2		2	1	1		1		1	1	1					11
3– 4				1	3	5	6	4	3	2	2	2			1				29
4– 5					2	9	4	4	1	2	2	1	1						26
5– 6						5	6	6	8	2	6		1	3	2	1			40
6– 7				1		2	5	7	6	8	1	3	4	2	2.	1	1	1	44
7– 8						1	1	5	5	2	4	2	1	1	1			1	24
8– 9							3	2	2	3	3	2	1			2			18
9–10						1			3	3	3	2	1	3			1		17
10–11										1	2	2	3	1					9
11–12								1				2		1	1				5
12–13												1	1						2
Totals	2	0	2	5	7	28	28	32	28	24	23	18	14	12	7	4	2	2	238

FIG. 145.— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative*

r = .492 ± 033

Series 100

	4–5	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	25–26	27–28	Totals
0–1	1	2	1	3	10	10	11	7	1													46
1–2						2	8	8	18	16	9	7	1	5	3							77
2–3							3	7	6	16	12	7	10	7	4	1	2		1			76
3–4								2	2	12	10	4	5	4	5	1						45
4–5									1	5	9	3		2	2	1					1	24
5–6									1	3	4	2	4	1	1	2						18
6–7										2	1	1	2	1	2			1		1		11
7–8														1								1
8–9														1				1				2
Totals	1	2	1	3	10	12	22	24	29	54	45	24	22	22	17	5	2	2	1	1	1	300

FIG. 146.*— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative*

$r = .585 \pm .026$

* See footnote to Fig. 73, page 955

Series 122

	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	30–31	Totals
0–1	1	5	8	9	11	17	7	7	4	4	3	1		1						78
1–2						5	10	12	12	12	12	15	15	1	1			1		96
2–3							2	2	4	13	10	12	10	11	3	3	1		1	72
3–4							1	2	2	1	6	6	7	4	2	4	1	1		37
4–5										2	1	3	3	2			1			12
5–6														1	3					4
6–7																		1		1
Totals	1	5	8	9	11	22	20	23	22	32	32	37	35	20	9	7	3	3	1	300

FIG. 147.*— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative*

r = 652 ± .022

*See footnote to Fig. 73, page 955.

error. In line 62 the greatest correlation is found where crowding is medium, and the least correlation where crowding is least. For series 102 the coefficient is .583 ± .026, and for series 68 it is .525 ± .028; the extreme difference being .058 ± .038, which is only about half as much

Series 68

	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	Totals
0–1	3	2	1	1									7
1–2	3	2	2	7	3	2	2						21
2–3		4	5	7	3	4	1	2					26
3–4			8	6	16	6	7	5	4		1		53
4–5		1	6	9	13	14	6	1	4	1			55
5–6			1	2	10	14	10	5					42
6–7				3	7	17	7	6	1				41
7–8				3	5	8	8	8	2	3			37
8–9						1	6	4		1			12
9–10							3	2	1				6
Totals	6	9	23	38	57	66	50	33	12	5	1	0	300

FIG. 148.— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative*

r = .525 ± .028

Series 102

	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	Totals
0–1	8	6	8	5	5	8	11	9	1	2						63
1–2				1	3	5	15	11	18	11	10	2	2			78
2–3						1	7	13	17	11	3	5	2			59
3–4						1	1	14	8	10	4		1	1		40
4–5								4	8	3	11	4	1		1	32
5–6								1	4	4	3		1			13
6–7									1	5	2	4	2			14
7–8																0
8–9											1					1
Totals	8	6	8	6	8	15	34	52	57	46	34	15	9	1	1	300

FIG. 149.— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative*
r = .583 ± 026

more than its probable error. There is, then, only a slight tendency shown for the correlation between yield and average weight of kernels to increase as crowding increases.

Series 118

	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	20–21	Totals
0–1	1	3	8	19	25	26	27	20	16	6	1	1				153
1–2						2	8	14	17	20	14	7	3		1	86
2–3						2		7	10	8	8	3	1	1		40
3–4								3	5	4		1		2		15
4–5										2	1	1	1			5
5–6											1					1
Totals	1	3	8	19	25	30	35	44	48	40	25	13	5	3	1	300

FIG. 150.*— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of kernels per plant, in milligrams, relative*
r = .568 ± 026

* See footnote to Fig. 73, page 955

Very different results from those that have heretofore been encountered in these lines are found when average yield of culm per plant is correlated with average number of kernels per spikelet of plant (Figs. 151 to 156). In both lines there is a graduated increase from the condition of least crowding to that of most crowding. In line 59 the extremes are found in series 63 and series 122, the respective coefficients being —.025 ± .044 and .489 ± .030, an extreme difference of .514 ± .053, which is nearly ten times its probable error. In line 62 the extremes are in series 68 and series 118, being .060 ± .039 and .621 ± .024, respectively — an extreme difference of .561 ± .046, which is about twelve times its probable error. There is, then, a decided and significant increase in correlation between yield and number of kernels per spikelet as crowding increases. The means and the standard deviations for the former character decreased with crowding; for the latter character there was not much difference produced by crowding.

Series 63

	1.55–1.65	1.65–1.75	1.75–1.85	1.85–1.95	1.95–2.05	2.05–2.15	2.15–2.25	2.25–2.35	2.35–2.45	2.45–2.55	2.55–2.65	2.65–2.75	2.75–2.85	2.85–2.95	2.95–3.05	Totals
1– 2			1	2	6	1	1				1	1				13
2– 3	1		1	3		1		2			2				1	11
3– 4		2	4	4	4	2	5	4	1		3					29
4– 5		1	3	9	3	6	2		1	1						26
5– 6		2	5	15	4	6	4		1	2		1				40
6– 7		1	2	12	10	3	5	2	1	2	3	2	1			44
7– 8			2	8	7		3	1	1		1	1				24
8– 9		1	1	1	6	4	2	1		1			1			18
9–10				5	4	2		3	1	1		1				17
10–11			1	3	3		1			1						9
11–12				1	3			1								5
12–13		1			1											2
Totals	1	8	20	63	51	25	23	14	6	8	10	6	2	0	1	238

FIG. 151.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per spikelet of plant, relative*
$r = -.025 \pm .044$

Series 100

	1.35–1.45	1.45–1.55	1.55–1.65	1.65–1.75	1.75–1.85	1.85–1.95	1.95–2.05	2.05–2.15	2.15–2.25	2.25–2.35	2.35–2.45	2.45–2.55	2.55–2.65	2.65–2.75	2.75–2.85	2.85–2.95	2.95–3.05	3.05–3.15	3.15–3.25	Totals
0–1	1	2	2	13	2		26													46
1–2		1	2	7	11	3	40	2	10			1								77
2–3			2	1	5	9	17	9	3	11	5	5	4	3	1		1			76
3–4					2	4	7	9	1	4	4	1	2	5	1	3		1	1	45
4–5					2	3	4	4	4	2	1		3	1						21
5–6					3		1		5	2	4	2		1						18
6–7						2	3	1		2		2	1							11
7–8									1											1
8–9						1							1							2
Totals	1	3	6	21	25	22	98	25	24	21	14	11	11	10	2	3	1	1	1	300

FIG. 152.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per spikelet of plant, relative*

r = .404 ± .033

Series 122

	0.95–1.05	1.05–1.15	1.15–1.25	1.25–1.35	1.35–1.45	1.45–1.55	1.55–1.65	1.65–1.75	1 75–1.85	1.85–1 95	1 95–2 05	2 05–2 15	2 15–2.25	2 25–2.35	2 35–2 45	2 45–2.55	2 55–2.65	2 65–2.75	2 75–2 85	2 85–2.95	2.95–3.05	Totals
0–1	1			5		11	1	15			45											78
1–2					2		3	10	17	1	54		5	1	1			1			1	96
2–3							1	3	1	8	26	5	11	7		1	3	1	3		2	72
3–4								1	3	5	8	5	1	1	4	1	3	2	2	1		37
4–5										1	1	4	2	1	1		1	1				12
5–6									1				1				1				1	4
6–7													1									1
Totals	1	0	0	5	2	11	5	29	22	15	134	14	21	10	6	2	8	5	5	1	4	300

FIG. 153.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per spikelet of plant, relative*

$r = .489 \pm .030$

Series 68	1 35–1 45	1 45–1 55	1.55–1 65	1 65–1.75	1 75–1 85	1 85–1 95	1 95–2 05	2 05–2.15	2 15–2 25	2 25–2 35	2 35–2 45	2 45–2 55	2 55–2 65	2 65–2 75	2 75–2.85	2 85–2 95	2 95–3 05	Totals
0– 1			2				4							1				7
1– 2				1	2	1	9		2	2	2		1	1				21
2– 3		1		1	4	5	7	2	1	1		1	1	1			1	26
3– 4				1	2	13	8	9	2	4	2	2	2	3	1		4	53
4– 5					4	10	11	7	4	3	4	5	1	2	2	1	1	55
5– 6	1				1	5	16	9	2	3		1	3	1				42
6– 7				1	2	5	19	3	4	2	1	2	1	1				41
7– 8					1	3	10	10	5		3	2	2		1			37
8– 9					1	1	7	2	1									12
9–10						2		2	1						1			6
Totals	1	1	2	4	17	45	91	44	22	15	12	13	11	10	5	1	6	300

FIG. 154.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per spikelet of plant, relative*

r = 060 ± .039

Series 102

	0.95–1.05	1 05–1.15	1 15–1.25	1 25–1 35	1 35–1 45	1 45–1 55	1 55–1.65	1.65–1 75	1 75–1.85	1.85–1 95	1 95–2 05	2 05–2 15	2 15–2 25	2 25–2 35	2 35–2.45	2 45–2.55	2 55–2 65	2 65–2 75	2 75–2 85	2 85–2 95	2 95–3 05	Totals
0–1	4		1	1		9	1	10	7		29							1				63
1–2						1	2	6	9	8	24	3	4	3	4	2	4	2	3		3	78
2–3							1	2	3	2	9	8	9	6	6	5	1	3	1		3	59
3–4									1	6	4	5	5	7	4	2	2		2	1	1	40
4–5										2	3	5	3	3	3	3	4	4	1		1	32
5–6											1	1	1	2	2	2	1	1	1	1		13
6–7										1	3	2	1	1	1		1	1	1	1	1	14
7–8																						0
8–9														1								1
Totals	4	0	1	1	0	10	4	18	20	19	73	24	23	23	20	14	13	12	9	3	9	300

FIG. 155.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per spikelet of plant, relative*

r = .474 ± .030

Series 118

	0 95–1.05	1.05–1.15	1.15–1.25	1.25–1.35	1 35–1.45	1 45–1.55	1.55–1 65	1 65–1.75	1 75–1.85	1 85–1 95	1 95–2 05	2 05–2 15	2 15–2 25	2 25–2 35	2 35–2.45	2 45–2 55	2 55–2.65	2 65–2.75	2 75–2 85	2 85–2 95	2 95–3 05	Totals
0–1	2			2		11	1	22	6		107		1								1	153
1–2							2	2	7	5	49	4	3	6			2	2	3		1	86
2–3										1	4	9	4	6	6	3	4			2	1	40
3–4												1	2		1	2	4	1	1	1	2	15
4–5													1		1	1	1			1		5
5–6															1							1
Totals	2	0	0	2	0	11	3	24	13	6	160	14	11	12	9	6	11	3	4	4	5	300

FIG. 156.— *Correlation between average yield of culm per plant, in decigrams, subject; and average number of kernels per spikelet of plant, relative*

$r = .621 \pm .024$

For average yield of culm per plant and diameter of straw (Figs. 157 to 162), the correlation is highest in the medium condition of crowding, and lowest in the least condition of crowding, for both lines. In line 50 the highest and the lowest are .882 ± .009 and .765 ± .018,

Series 63

	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	34–36	Totals
1– 2	3	5	3		1	1						13
2– 3	2	2	2	1	2	1	1					11
3– 4			7	7	7	6	2					29
4– 5					5	9	9	1	2			26
5– 6					8	9	10	6	5	2		40
6– 7					3	7	19	7	6	2		44
7– 8						4	4	4	10	1	1	24
8– 9							5	6	6	1		18
9–10							2	6	2	7		17
10–11								2	2	2	3	9
11–12								2	2	1		5
12–13								1		1		2
Totals	5	7	12	8	26	37	52	35	35	17	4	238

FIG. 157.— *Correlation between average yield of culm per plant, in decigrams, subject; and diameter of straw, in decimillimeters, relative*

r = 765 ± 018

Series 100

	6– 8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	Totals
0–1	7	19	13	5	1	1							46
1–2		7	17	21	13	16	3						77
2–3				11	18	25	18	3	1				76
3–4					2	7	17	14	5				45
4–5							3	7	10	4			24
5–6							1		8	8	1		18
6–7									1	7	2	1	11
7–8											1		1
8–9											2		2
Totals	7	26	30	37	34	49	42	24	25	19	6	1	300

FIG. 158.— *Correlation between average yield of culm per plant, in decigrams, subject; and diameter of straw, in decimillimeters, relative*

r = .882 ± .009

Series 122

	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	Totals
0–1	1	3	16	34	18	5		1					78
1–2				5	16	47	18	8	2				96
2–3						2	23	31	15	1			72
3–4								8	18	7	3	1	37
4–5									4	5	2	1	12
5–6									1	3			4
6–7											1		1
Totals	1	3	16	39	34	54	41	48	40	16	6	2	300

FIG. 159.—*Correlation between average yield of culm per plant, in decigrams, subject; and diameter of straw, in decimillimeters, relative*
r = .866 ± .010

respectively. In line 62 the extremes are .878 ± .009 and .785 ± .015. The difference in each case, .117 ± .020 for line 50 and .093 ± .017 for line 62, is more than five times its probable error. This difference may

Series 68

	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32	32–34	Totals
0– 1	3	1	1	2										7
1– 2		2	4	5	7	3								21
2– 3				1	5	14	4		1	1				26
3– 4					2	8	16	9	9	7	2			53
4– 5						2	7	18	15	11	2			55
5– 6							1	5	14	15	6	1		42
6– 7							1	5	7	12	8	7	1	41
7– 8							1	1	6	17	10	1	1	37
8– 9										4	5	3		12
9–10								1		2	2		1	6
Totals	3	3	5	8	14	27	30	39	52	69	35	12	3	300

FIG. 160.—*Correlation between average yield of culm per plant, in decigrams, subject; and diameter of straw, in decimillimeters, relative*
r = .785 ± .015

Series 102

	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	Totals
0–1	3	8	16	15	17	3	1							63
1–2				1	21	27	23	5	1					78
2–3						5	16	17	15	4	1	1		59
3–4								7	15	14	2	2		40
4–5								2	4	15	8	3		32
5–6										5	5	1	2	13
6–7										1	4	9		14
7–8														0
8–9												1		1
Totals	3	8	16	16	38	35	40	31	35	39	20	17	2	300

FIG. 161.— *Correlation between average yield of culm per plant, in decigrams, subject; and diameter of straw, in decimillimeters, relative*

r = 878 ± .009

be of some importance. It seems that, up to a certain point, as crowding increases the correlation between yield and diameter of straw increases, and that beyond this point there is a decrease in correlation.

Series 118

	4–6	6–8	8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	Totals
0–1	11	37	52	34	15	4						153
1–2				12	40	25	8			1		86
2–3						2	19	15	4			40
3–4								7	8			15
4–5									2	3		5
5–6											1	1
Totals	11	37	52	46	55	31	27	22	14	4	1	300

FIG. 162.— *Correlation between average yield of culm per plant, in decigrams, subject; and diameter of straw, in decimillimeters, relative*

r = 871 ± 009

Comparing average yield of culm per plant and breaking strength of straw (Figs. 163 to 168), it is seen that there is again a significant difference in correlation produced by crowding. In both lines the lowest

Series 63

	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	220–240	240–260	260–280	280–300	300–320	320–340	340–360	360–380	380–400	400–420	420–440	440–460	520–540	Totals
1–2	2	5	2	2		1	1																13
2–3	1	2	1	1	2	2				2													11
3–4		1	2	5	5	5	2	4	2	1			1		1								29
4–5				2	3	1	1	3	3	3	4	4	1			1							26
5–6					2	1	8	7	1	4	7	3	2		3	2							40
6–7					1	1	4	10	6	4	7	1	2	3		2	1	1			1		44
7–8							2	2	1	3	3	2	1	5	2	1	1		1				24
8–9									3	2	7	1	1		3		1						18
9–10										1	5	3	2	1	1	2	1					1	17
10–11									1				2			1		2	1		2		9
11–12											1		3	1									5
12–13														1	1								2
Totals	3	8	5	10	13	11	18	26	17	20	34	14	15	11	11	9	4	3	2	0	3	1	238

FIG. 163.*— *Correlation between average yield of culm per plant, in decigrams, subject; and breaking strength of straw, in grams, relative*

$r = 673 \pm .024$

* See footnote to Fig. 73, page 955.

Series 100

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	220–240	240–260	260–280	Totals
0–1	1	18	21	5	1										46
1–2			13	29	25	8	2								77
2–3				8	26	27	11	3	1						76
3–4					3	12	18	7	3	2					45
4–5							7	12	2	2	1				24
5–6							1	2	6	5	3		1		18
6–7									2	4	3	1	1		11
7–8									1						1
8–9												1		1	2
Totals	1	18	34	42	55	47	39	24	15	13	7	2	2	1	300

FIG. 164.— *Correlation between average yield of culm per plant, in decigrams, subject; and breaking strength of straw, in grams, relative*

r = .896 ± 008

correlation occurs when least crowding exists. In line 50, series 63, the coefficient is .673 ± .024, this being the lowest coefficient. The highest is .896 ± .008, for series 100, the difference being .223 ± .025, which is significant. In line 62 the extreme coefficients differ by .182 ± .022,

Series 122

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	Totals
0–1	15	49	11	3								78
1–2		4	50	27	11	3	1					96
2–3				13	31	18	8	2				72
3–4					5	16	8	4	3		1	37
4–5						1	6	3		2		12
5–6							1	2		1		4
6–7								1				1
Totals	15	53	61	43	47	38	24	12	3	3	1	300

FIG. 165.— *Correlation between average yield of culm per plant, in decigrams, subject; and breaking strength of straw, in grams, relative*

r = .870 ± 009

Series 68

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	220–240	240–260	260–280	280–300	300–320	320–340	340–360	360–380	380–400	400–420	420–440	440–460	Totals
0–1	1	1	3	1	1																			7
1–2		1	1	5	7	3	3	1																21
2–3			1	3	7	7	2	1	1		2		1		1									26
3–4				1	2	3	11	7	8	4	3	7	2	2	3									53
4–5					1		4	7	6	11	7	7	6	4	2									55
5–6							2	1	5	3	4	12	5	4	1	2	1	1	1					42
6–7								1	4		6	4	5	5	4	6	1	1	1	2			1	41
7–8							2				4	8	7	4	7	3	1			1				37
8–9											3	2		1			5	1						12
9–10									1			1	1					1	1		1			6
Totals	1	2	5	10	18	13	24	18	25	18	29	41	27	20	18	11	8	4	3	3	1	0	1	300

FIG. 166.—*Correlation between average yield of culm per plant, in decigrams, subject; and breaking strength of straw, in grams, relative*

r = .701 ± 020

Series 102

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	220–240	240–260	260–280	Totals
0–1	22	33	8												63
1–2		8	34	30	5		1								78
2–3			3	23	16	12	4	1							59
3–4				1	10	10	12	3	1	1	1	1			40
4–5					1	8	11	4	5	2	1				32
5–6				1		1	4	3		1		1	1	1	13
6–7							1	5	4	2	2				14
7–8															0
8–9									1						1
Totals	22	41	45	55	32	31	33	16	11	6	4	2	1	1	300

FIG. 167.— *Correlation between average yield of culm per plant, in decigrams, subject; and breaking strength of straw, in grams, relative*

r = 863 ± 010

which is also significant. In this line the greatest correlation is found with the greatest crowding. It appears, then, that there is an increase in correlation with increase in crowding, but that the limit is reached more quickly in line 50.

Series 118

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	Totals
0–1	39	78	30	6						153
1–2		4	24	37	19	1	1			86
2–3			1	6	9	16	8			40
3–4						3	5	7		15
4–5							1	2	2	5
5–6							1			1
Totals	39	82	55	49	28	20	16	9	2	300

FIG. 168.— *Correlation between average yield of culm per plant, in decigrams, subject; and breaking strength of straw, in grams, relative*

r = .883 ± .009

Average yield of culm per plant is correlated with average weight of straw per culm of plant (Figs. 169 to 174) in line 50 as follows: .901 ± .007 in series 122; .919 ± .007 in series 63; and .941 ± .004 in series 100. The difference of the extremes is here .040 ± .008, which is not highly

Series 63

	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	Totals
1– 2	2	11															13
2– 3		5	2	3		1											11
3– 4		2	14	8	5												29
4– 5				11	9	5	1										26
5– 6				4	14	12	10										40
6– 7					4	21	12	4	3								44
7– 8						2	5	12	5								24
8– 9							3	7	5	3							18
9–10								3	3	7	4						17
10–11									4	1	2	1	1				9
11–12										2	2				1		5
12–13										1						1	2
Totals	2	18	16	26	32	41	31	26	20	14	8	1	1	0	1	1	238

FIG. 169.— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative*

r = .919 ± .007

Series 100

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	Totals
0–1	4	32	10										46
1–2		13	40	24									77
2–3			8	36	24	7	1						76
3–4				1	20	18	6						45
4–5						4	12	8					24
5–6							1	9	6	2			18
6–7								1	5	4		1	11
7–8										1			1
8–9										1		1	2
Totals	4	45	58	61	44	29	20	18	11	8	0	2	300

FIG. 170.— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative*

r = .941 ± .004

Series 122

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	Totals
0–1	22	51	5							78
1–2		29	53	11	2		1			96
2–3			6	53	11	2				72
3–4				6	22	9				37
4–5					1	3	7	1		12
5–6						1	1	2		4
6–7									1	1
Totals	22	80	64	70	36	15	9	3	1	300

FIG. 171.— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative*

$r = .901 \pm 007$

significant. In line 62 the coefficients are, in order of value: .884 ± .008 in series 68; .888 ± .008 in series 118; and .944 ± .004 in series 102. The difference of the extremes is here .060 ± .009, which is probably of some significance. From these results it is evident that yield and weight of straw are highly correlated in the culms of oat plants. This correlation

Series 68

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	Totals
0– 1	1	3	3												7
1– 2		1	13	6	1										21
2– 3			5	12	8	1									26
3– 4				13	21	17	2								53
4– 5					14	22	17	2							55
5– 6						11	18	12	1						42
6– 7						3	13	9	11	4			1		41
7– 8							4	11	14	6	1			1	37
8– 9							2		4	4		1	1		12
9–10									1	3	1	1			6
Totals	1	4	21	31	44	54	56	34	31	17	2	2	2	1	300

FIG. 172.— *Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative*

$r = .884 \pm .008$

Series 102

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	Totals
0–1	19	39	5										63
1–2		15	51	11	1								78
2–3			4	37	17			1					59
3–4				1	19	14	6						40
4–5					2	11	13	5	1				32
5–6							6	4	1	1	1		13
6–7							1	2	7	4			14
7–8													0
8–9												1	1
Totals	19	54	60	49	39	25	26	12	9	5	1	1	300

FIG. 173.—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative*

$r = .944 \pm 004$

is increased to a small extent when plants are grown in more crowded conditions up to a certain limit, beyond which the correlation is again reduced.

Series 118

	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	Totals
0–1	60	84	8	1					153
1–2		25	48	13					86
2–3			7	28	5				40
3–4					10	3	2		15
4–5						4	1		5
5–6								1	1
Totals	60	109	63	42	15	7	3	1	300

FIG. 174.—*Correlation between average yield of culm per plant, in decigrams, subject; and average weight of straw per culm of plant, in decigrams, relative*

$r = .888 \pm .008$

Interesting conditions are found when diameter of straw is correlated with breaking strength of straw (Figs. 175 to 180). The highest correlation in line 50 is in the most crowded condition, where the coefficient

Series 63

	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	220–240	240–260	260–280	280–300	300–320	320–340	340–360	360–380	380–400	400–420	420–440	440–460	520–540	Totals
14–16	2	2	1																				5
16–18		4	1	2																			7
18–20		1	2	2	6	1																	12
20–22		1		3	1	2	1																8
22–24				2	3	6	3	10	1	1													26
24–26	1		1	1	1	2	10	7	6	3	2	2	1										37
26–28					2		3	6	6	13	10	5	2		3	2							52
28–30							1	2	3	1	12	2	4	5	2	1	1				1		35
30–32								1	1	2	9	4	5	3	3	2	2	2			1		35
32–34											1	1	2	3	3	3	1		1		1	1	17
34–36													1			1		1	1				4
Totals	3	8	5	10	13	11	18	26	17	20	34	14	15	11	11	9	4	3	2	0	3	1	238

FIG. 175.*— *Correlation between diameter of straw, in decimillimeters, subject; and breaking strength of straw, in grams, relative*

r = .820 ± .014

* See footnote to Fig. 73, page 955.

Series 100

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	220–240	240–260	260–280	Totals
6– 8	1	4	2												7
8–10		8	8	8	2										26
10–12		5	11	6	6	2									30
12–14		1	10	11	8	5		2							37
14–16			2	7	12	10	3								34
16–18			1	9	14	12	12		1						49
18–20				1	11	14	11	4	1						42
20–22					2	4	7	9	1	1					24
22–24							6	8	7	2	2				25
24–26								1	3	7	5	1	2		19
26–28									2	2		1		1	6
28–30										1					1
Totals	1	18	34	42	55	47	39	24	15	13	7	2	2	1	300

FIG. 176.— *Correlation between diameter of straw, in decimillimeters, subject; and breaking strength of straw, in grams, relative*
r = 852 ± .011

is .913 ± .006. From this the decrease is graduated to the least crowded condition, where the coefficient is .820 ± .014. The difference is .093 ± .015, which is about six times its probable error. In line 62 the correlations are not graduated in the same order. The lowest again occurs in the

Series 122

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	Totals
2– 4	1											1
4– 6	3											3
6– 8	7	9										16
8–10	4	30	4	1								39
10–12		10	20	4								34
12–14		3	30	19	2							54
14–16			7	14	16	4						41
16–18		1		5	22	14	6					48
18–20					7	19	9	4	1			40
20–22						1	9	5		1		16
22–24								3	2	1		6
24–26										1	1	2
Totals	15	53	61	43	47	38	24	12	3	3	1	300

FIG. 177.— *Correlation between diameter of straw, in decimillimeters, subject; and breaking strength of straw, in grams, relative*
r = .913 ± .006

Series 68

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	220–240	240–260	260–280	280–300	300–320	320–340	340–360	360–380	380–400	400–420	420–440	440–460	Totals
8–10	1	1	1																					3
10–12		1	1	1																				3
12–14			1	3	1																			5
14–16			1		4	2	1																	8
16–18			1	3	6	1	2	1																14
18–20				3	4	6	8	5	1															27
20–22					1	4	6	5	7	2	4	1												30
22–24					2		3	5	12	8	4	3		1	1									39
24–26							2	1	4	5	10	14	9	3	3	1								52
26–28							2	1	1	3	6	17	12	10	8	6	1	2						69
28–30											5	6	6	5	5	1	3	1	2	1				35
30–32														1	1	3	4	1	1				1	12
32–34																				2	1			3
Totals	1	2	5	10	18	13	24	18	25	18	29	41	27	20	18	11	8	4	3	3	1	0	1	300

FIG. 178.— *Correlation between diameter of straw, in decimillimeters, subject; and breaking strength of straw, in grams, relative*

r = 871 ± 009

Series 102

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	180–200	200–220	220–240	240–260	260–280	Totals
4–6	3														3
6–8	7	1													8
8–10	10	6													16
10–12	1	14	1												16
12–14	1	14	20	3											38
14–16		6	15	14											35
16–18			7	23	8	2									40
18–20			1	11	11	4	4								31
20–22			1	3	9	13	7	2							35
22–24				1	3	11	16	5	2	1					39
24–26					1	1	4	7	4	2	1				20
26–28							2	2	5	3	3	1	1		17
28–30												1		1	2
Totals	22	41	45	55	32	31	33	16	11	6	4	2	1	1	300

FIG. 179.— *Correlation between diameter of straw, in decimillimeters, subject; and breaking strength of straw, in grams, relative*
$r = .960 \pm .003$

least crowded condition, but the highest is in the medium condition of crowding. The difference is here .089 ± .009, which is great enough to be of significance. The diameter of straw is, then, highly correlated with breaking strength, and the lowest correlation occurs when crowding is least.

Series 118

	0–20	20–40	40–60	60–80	80–100	100–120	120–140	140–160	160–180	Totals
4–6	11									11
6–8	22	15								37
8–10	6	40	6							52
10–12		22	21	2	1					46
12–14		5	21	24	5					55
14–16			6	13	10	1	1			31
16–18			1	7	8	7	4			27
18–20				2	3	8	6	3		22
20–22					1	4	3	4	2	14
22–24				1			1	2		4
24–26							1			1
Totals	39	82	55	49	28	20	16	9	2	300

FIG. 180.— *Correlation between diameter of straw, in decimillimeters, subject; and breaking strength of straw, in grams, relative*
$r = .899 \pm .007$

When average weight of kernels is concerned in correlation, there is always the lowest correlation for the plants grown in the least crowded condition. There is usually, but not always, the greatest correlation in plants grown under the most crowded conditions. The differences, too, are usually of significant value. When average weight of kernels per plant is correlated with average number of kernels per culm of plant (Figs. 181 to 186), it is seen that in line 50 the extreme coefficients are .133 ± .043 for series 63, and .466 ± .030 for series 122 — a difference of .333 ± .052, which is more than six times its probable error. In line 62 the extreme coefficients are .288 ± .036 for series 68, and .487 ± .030 for series 118. The difference here is .199 ± .047, which is more than four times its probable error.

Series 63

	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	68–72	Totals
9–10			1		1												2
10–11																	0
11–12		2															2
12–13		1	1	1		1					1						5
13–14	1	1		2	1		2										7
14–15	2	2	1	1	7	4	4	3	1	1	1			1			28
15–16	2	1	1	5	1	3	5	1	4	2	1	2					28
16–17	2	1	1	4	2	2	5	6	5	2	1					1	32
17–18			2	2	1	6	3	5	4	1	3	1					28
18–19		2	1		2	2	7	1	3	2	3	1					24
19–20			2		8		2	2	2	3	2	2					23
20–21		2	1	1		3	1	1	3		3	2	1				18
21–22		1		1	1	4		2		4			1				14
22–23	1			2	2	1	1	1	2	1	1						12
23–24		1		1	2	2				1							7
24–25				1	1		2										4
25–26					1			1									2
26–27					2												2
Totals	8	14	11	21	32	28	32	23	24	17	16	8	2	1	0	1	238

FIG. 181.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative*

r = .133 ± .043

Series 100

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	Totals
4–5	1											1
5–6												0
6–7	1	1										2
7–8		1										1
8–9	1	1	1									3
9–10		7	3									10
10–11	1	9	2									12
11–12	1	10	3	5	1		2					22
12–13		8	5	4	2	4	1					24
13–14		5	10	6	4		1	2		1		29
14–15		5	10	9	8	8	4	4	2	2	2	54
15–16			6	11	7	5	7	4	2	3		45
16–17		1	6	4	5	2	1	3	1	1		24
17–18			2	8	3	3		3	2	1		22
18–19		3	5	5	3	2		2		1	1	22
19–20		3	2	5	2	2	1		2			17
20–21				2		1	2					5
21–22			2									2
22–23								1		1		2
23–24			1									1
24–25												0
25–26							1					1
26–27												0
27–28				1								1
Totals	5	54	58	60	35	27	20	19	9	10	3	300

FIG. 182.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative*

$r = .363 \pm .034$

Series 122

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	Totals
6– 7	1								1
7– 8	5								5
8– 9	4	4							8
9–10	6	3							9
10–11	5	6							11
11–12	5	12	3	1	1				22
12–13		7	6	4		3			20
13–14	3	7	6	4	1	1	1		23
14–15	3	7	4	3	3		2		22
15–16	1	7	8	7	6	1	1	1	32
16–17		9	6	7	3	6		1	32
17–18		6	13	9	3	3	3		37
18–19		9	10	6	7	1	2		35
19–20	1	1	2	10	3	1	2		20
20–21			4	1	1		3		9
21–22			1	6					7
22–23			1	1		1			3
23–24		1		1			1		3
30–31			1						1
Totals	34	79	65	60	28	17	15	2	300

FIG. 183.*—*Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative*

r = .466 ± .030

* See footnote to Fig. 73, page 955.

Series 68

	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	60–64	64–68	Totals
8– 9	2	1	2		1												6
9–10	1	1	2		2	1	1				1						9
10–11	1			3	3	1	4	4	3	1	3						23
11–12	1	1	6	2	2	4	4	1	6	3		4	1	1	2		38
12–13		1	2	1	3	6	9	8	6	4	5	3	4	2	3		57
13–14		2	1	2	2	4	10	3	8	10	12	5	4	2	1		66
14–15		2	1		1	7	1	7	5	7	2	4	7	2	4		50
15–16				3	2	2	1	3	2	5	7	2	4	1		1	33
16–17				2	2	2	2		1		2			1			12
17–18						1				2	2						5
18–19					1												1
Totals	5	8	14	13	19	28	32	26	31	32	34	18	20	9	10	1	300

FIG. 184.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative*

r = .288 ± .036

Series 102

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	40–44	44–48	48–52	52–56	56–60	Totals
3–4	4	4														8
4–5	3	3														6
5–6	4	3	1													8
6–7	2	2	1				1									6
7–8	1	2	2	3												8
8–9	1	2	6	2	1	2				1						15
9–10	1	3	7	5	9	6	2		1							34
10–11	1	8	4	6	3	7	4	7	5	4	2		1			52
11–12		1	8	10	6	7	4	6	3	4	4	2	1		1	57
12–13		3	5	6	6	5	8	1	1	2	1	4	1	3		46
13–14			8	4		2	3	3	6	2	3	1	1		1	34
14–15			2	1	4			3	1		3	1				15
15–16		1	1	1	1		2			2	1					9
16–17			•			1										1
17–18						1										1
Totals	17	32	45	38	30	31	24	20	17	15	14	8	4	3	2	300

FIG. 185.—*Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative*

r = 471 ± 030

Series 118

	0–4	4–8	8–12	12–16	16–20	20–24	24–28	28–32	32–36	36–40	Totals
3–4	1										1
4–5	3										3
5–6	6	2									8
6–7	12	7									19
7–8	9	13	3								25
8–9	9	13	5	1		1		1			30
9–10	5	16	12	1	1						35
10–11	3	15	11	3	2	4	3	3			44
11–12	3	13	7	10	6	3	2	3	1		48
12–13	1	6	12	8	4	3	3	1	2		40
13–14		3	10	5	3	2		1		1	25
14–15		1	5	2	3	1		1			13
15–16			3	1				1			5
16–17			1		1	1					3
20–21		1									1
Totals	52	90	69	31	20	15	8	11	3	1	300

FIG. 186.*—*Correlation between average weight of kernels per plant, in milligrams, subject; and average number of kernels per culm of plant, relative*

r = .487 ± .030

*See footnote to Fig. 73, page 955

For average weight of kernels per plant correlated with average height of plant (Figs. 187 to 192), the extreme coefficients are, in line 50, .380 ± .037 for series 63, and .718 ± .019 for series 122 — a difference of .338 ± .042, which is about eight times its probable error. In line 62 the extreme coefficients are .450 ± .031 for series 68, and .733 ± .018 for series 102 — a difference of .283 ± .036, or about eight times its probable error.

Series 63

	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	Totals
9–10					1	1						2
10–11												0
11–12	1		1									2
12–13		1	1	1			2					5
13–14			1	2		2	1	1				7
14–15			2	1	4	13	4	2	2			28
15–16				4	4	6	6	4	4			28
16–17	1		1	2	4	5	7	8	2	2		32
17–18				3	4	6	6	5	2	1	1	28
18–19			2	3	1		8	3	6	1		24
19–20				1	2	5	4	4	2	4	1	23
20–21			2		1		3	4	3	4	1	18
21–22				1	1	2	1	4	1	3	1	14
22–23			1		1		3	2	3	2		12
23–24					1	1	1	2	1		1	7
24–25					1		1	1		1		4
25–26								1	1			2
26–27							1			1		2
Totals	2	1	11	18	25	41	48	41	27	19	5	238

FIG. 187.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative*

$r = .380 \pm .037$

Series 100

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	Totals
4– 5		1											1
5– 6													0
6– 7		1		1									2
7– 8		1											1
8– 9		1	1	1									3
9–10		1	4	4	1								10
10–11		3	7	2									12
11–12	1	3	2	5	4	4	2	1					22
12–13			3	4	5	5	5	2					24
13–14		1	1	1	9	6	7	3	1				29
14–15			3	1	6	10	7	14	10	2	1		54
15–16				1	3	7	7	11	12	4			45
16–17			1		2	5	3	6	4	3			24
17–18					1	2	3	7	4	3	2		22
18–19					1	7	3	3	3	2	3		22
19–20				1	2	1	2	3	4	4			17
20–21								2		2	1		5
21–22						1		1					2
22–23												2	2
23–24								1					1
24–25													0
25–26										1			1
26–27													0
27–28										1			1
Totals	1	12	22	21	34	48	39	54	38	22	7	2	300

FIG. 188.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative*
$r = .651 \pm .022$

Series 122

	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	Totals
6– 7		1										1
7– 8		3	1	1								5
8– 9		3	5									8
9–10			5	3	1							9
10–11		2	3	4	1	1						11
11–12		1	6	4	7	3		1				22
12–13			2	2	6	4	4	2				20
13–14			1	4	5	6	3	2	1	1		23
14–15			2	1	5	5	6	1	1	1		22
15–16	2				3	9	5	6	6		1	32
16–17					3	6	12	4	6	1		32
17–18					4	3	11	4	13	2		37
18–19					2	8	6	12	5	1	1	35
19–20					1	2	1	9	3	3	1	20
20–21							2	3	1	2	1	9
21–22								2	5			7
22–23									2	1		3
23–24					1				1		1	3
30–31										1		1
Totals	2	10	25	19	39	47	50	46	44	13	5	300

FIG. 189.*— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative*

r = .718 ± .019

*See footnote to Fig. 73, page 955.

Series 68

	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	80–85	85–90	90–95	Totals
8– 9	1		2	1	1	1								6
9–10	1		2	1	1	4								9
10–11		1			3	10	8		1					23
11–12		2	1	2	5	7	5	10	2	3		1		38
12–13		1		3	4	13	9	15	6	5	1			57
13–14			1	2	4	9	14	14	11	9	2			66
14–15			1	2	1	4	9	13	7	8	1	3	1	50
15–16			1	1	1	2	2	6	7	6	6	1		33
16–17				1	1		4	1	2		3			12
17–18								2			3			5
18–19						1								1
Totals	2	4	8	13	21	51	51	61	36	31	16	5	1	300

FIG. 190.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative*

r = .450 ± .031

Series 102

	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	Totals
3– 4		1	3	1	2	1									8
4– 5	1	1	1	3											6
5– 6				6	1	1									8
6– 7					3	2			1						6
7– 8				3		2	3								8
8– 9			1		3	3	5	2			1				15
9–10			1		1	7	4	8	10	3					34
10–11					2	3	8	8	9	9	9	2	1	1	52
11–12						2	5	5	14	13	7	10	1		57
12–13						1	3	5	10	10	8	5	3	1	46
13–14							1	4	9		6	8	5	1	34
14–15								1	2	3	1	3	4	1	15
15–16									3		4	1	1		9
16–17												1			1
17–18												1			1
Totals	1	2	6	13	12	22	29	33	58	38	36	31	15	4	300

FIG. 191.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative*

$r = .733 \pm .018$

Series 118

	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70	70–75	75–80	Totals
3– 4	1												1
4– 5	1	1	1										3
5– 6		1	6	1									8
6– 7	2	5	5	4	3								19
7– 8		1	8	8	8								25
8– 9		2	2	9	9	3	4		1				30
9–10			1	7	7	15	5						35
10–11				3	11	10	8	6	3	3			44
11–12		1		3	7	5	8	14	6	2	2		48
12–13					5	9	6	6	11	3			40
13–14						5	5	9	2	3	1		25
14–15							3	4	3	2		1	13
15–16						1	3				1		5
16–17							1	1	1				3
20–21							1						1
Totals	4	11	23	35	50	48	44	40	27	13	4	1	300

FIG. 192.*— *Correlation between average weight of kernels per plant, in milligrams, subject; and average height of plant, in centimeters, relative*

$r = .714 \pm .019$

* See footnote to Fig. 73, page 955.

For average weight of kernels per plant correlated with average length of head per plant (Figs. 193 to 198), in line 50, for series 63 the coefficient is .081 ± .043 and for series 122 it is .535 ± .028. The difference here is .454 ± .051, which is about nine times its probable error. In line 62 the extreme difference is .341 ± .044, which is nearly eight times its probable error.

Series 63

	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	Totals
9–10				1			1					2
10–11												0
11–12		2										2
12–13				1	1	2				1		5
13–14			1	2		3	1					7
14–15	2		3		3	7	5	2	4	1	1	28
15–16		2	1	3		7	4	7	2	2		28
16–17	1	1	2	4	2	1	5	9	6	1		32
17–18				2	1	8	5	7	3	2		28
18–19			2	2	2	1	6	5	3	3		24
19–20	1			1	3	5	3	7	1	2		23
20–21			2		2	2	3	1	3	4	1	18
21–22		1		1	2		4	3	1	1	1	14
22–23	1		1	1	2		2	3	1	1		12
23–24			1	1	2	1	1			1		7
24–25			1	1			2					4
25–26					1			1				2
26–27						2						2
Totals	5	6	14	20	21	39	42	45	24	19	3	238

FIG. 193.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average length of head per plant, in centimeters, relative*

$r = .081 \pm .043$

Series 100

	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	Totals
4–5	1												1
5–6													0
6–7	1		1										2
7–8		1											1
8–9		1		1	1								3
9–10		2	3	2	3								10
10–11		3	4	3	1	1							12
11–12		4	2	6	2	3	3	2					22
12–13			4	3	3	6	4	3	1				24
13–14			1	5	8	3	8		2	2			29
14–15			2	4	6	15	8	6	6	3	4		54
15–16				2	3	7	14	8	8	2		1	45
16–17				2	4	9	3		2	2		2	24
17–18					3	6	5	3	3	2			22
18–19			1	3	3	6	3	3		2	1		22
19–20				2	3	6	3		2	1			17
20–21						1	3	1					5
21–22				1		1							2
22–23									2				2
23–24						1							1
24–25													0
25–26								1					1
26–27													0
27–28						1							1
Totals	2	11	18	34	40	66	54	27	26	14	5	3	300

FIG. 194.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average length of head per plant, in centimeters, relative*

$$r = .408 \pm .032$$

Series 122

	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	Totals
6– 7	1											1
7– 8		4	1									5
8– 9		4	3	1								8
9–10		2	4	2	1							9
10–11		2	5	4								11
11–12		2	6	6	6	1	1					22
12–13			1	5	1	7	3	1	2			20
13–14			5		7	5	2	2	1	1		23
14–15		1	2	4	4	3	3	3		2		22
15–16	1			4	4	8	8	2	2	3		32
16–17				5	6	7	4	6	2	2		32
17–18				4	4	10	8	8	2	1		37
18–19				4	6	7	10	4	3	1		35
19–20				2		6	6	2	4			20
20–21						3	2	1	2	1		9
21–22					1	3	3					7
22–23							2		1			3
23–24				1		1		1				3
30–31					1							1
Totals	2	15	27	42	41	61	52	30	19	11	0	300

FIG. 195.*— *Correlation between average weight of kernels per plant, in milligrams, subject; and average length of head per plant, in centimeters, relative*

r = .535 ± .028

*See footnote to Fig. 73, page 955

Series 68

	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	Totals
8– 9	2	1		1	2							6
9–10	1		2	2	1	2	1					9
10–11		1	1	2	3	5	6	2	3			23
11–12	1	1	3	2	5	10	8	4	3		1	38
12–13		1	1		12	11	10	14	5	3		57
13–14		1	2	1	9	4	22	19	6	1	1	66
14–15			3	3	3	8	12	8	7	5	1	50
15–16			1	1	5	3	7	9	7			33
16–17				1	4	2	2		2	1		12
17–18				1			3		1			5
18–19				1								1
Totals	4	5	13	15	44	45	71	56	34	10	3	300

FIG. 196.— *Correlation between average weight of kernels per plant, in milligrams, subject; and average length of head per plant, in centimeters, relative*

r = .265 ± .036

Series 102

	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	Totals
3–4	3	1	2	2									8
4–5	1	1	4										6
5–6		1	6		1								8
6–7		1	1	2		1	1						6
7–8		1	1	1	2	1	2						8
8–9	1		2	1	4	3	1	1	1			1	15
9–10		1	1	1	7	7	7	9	1				34
10–11			2	7	4	6	4	11	12	5	1		52
11–12			1	1	9	8	6	12	10	8	2		57
12–13			1	2	4	3	11	9	9	5	2		46
13–14				2	5	3	7	6	3	7	1		34
14–15					2	2	2	3	4	2			15
15–16				1	1		2	3		1	1		9
16–17							1						1
17–18							1						1
Totals	5	6	21	20	39	34	45	54	40	28	7	1	300

FIG. 197.—*Correlation between average weight of kernels per plant, in milligrams, subject; and average length of head per plant, in centimeters, relative*

r = .535 ± .028

Series 118

	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	Totals
3–4		1										1
4–5		2	1									3
5–6		2	4	2								8
6–7	1	2	8	6	1	1						19
7–8		3	5	6	9		2					25
8–9	1	2	5	4	11	4	1		1	1		30
9–10		1	3	4	10	11	6					35
10–11			2	3	12	11	4	5	4	3		44
11–12		1	3		8	8	12	8	8			48
12–13				1	7	8	12	8	3	1		40
13–14				1	1	8	8	4	2		1	25
14–15						2	7	3	1			13
15–16						2	2		1			5
16–17						1	1			1		3
20–21					1							1
Totals	2	14	31	27	60	56	55	28	20	6	1	300

FIG. 198.*—*Correlation between average weight of kernels per plant, in milligrams, subject; and average length of head per plant, in centimeters, relative*

r = .606 ± .025

*See footnote to Fig. 73, page 955.

There is a decided increase, then, in the correlation of average weight of kernels per plant with height of plant, length of head, and average number of kernels per culm, as plants are crowded together more closely in the row. The same condition exists also when average weight of kernels is correlated with average yield of culm per plant, as noted above. In line 62, however, in two cases (with yield and with height of plant) the limit is reached at the medium condition of crowding, beyond which there is a decrease in correlation.

From the foregoing it is seen that different degrees of crowding in the row may produce striking differences in the correlation between certain characters of plants in the same pure line of oats.

The differences between the correlation coefficients when the same characters are correlated in line 50 range from a minimum of .024 ± .009 to a maximum of .514 ± .053. In line 62 the range of differences is from .021 ± .010 to .561 ± .046. The smallest range was obtained when average yield of culm per plant was correlated with average number of kernels per culm of plant in one case and with average number of spikelets per culm of plant in the other case, and the greatest range in both cases was obtained when the former character was correlated with average number of kernels per spikelet of plant.

Whenever the average weight of kernels per plant is correlated with another character there is always a considerable difference produced in correlation by crowding. In every case when this factor has been used, the lowest correlation has been found in conditions of least crowding. The greatest correlation has usually been found in the condition of greatest crowding. In two cases, however, both in line 62, the greatest correlation is found in the intermediate condition, these cases being, respectively, with yield and with height of plant. It will be remembered that the crowding in series 118 is the greatest that is dealt with, being considerably more than that in series 122 (Table 11, page 1016). There appears, then, to be a point beyond which certain correlations decrease.

The correlation between yield and other characters is changed by more than .050 in six cases out of nine in both lines dealt with: in line 50 the six relative characters are height, length of head, weight of kernels, diameter of straw, number of kernels per spikelet, and breaking strength of straw; in line 62 weight of straw is substituted for length of head, the other characters being the same.

Yield increases slightly in its correlation with height as crowding increases up to a certain point, beyond which there is a gradual decrease in correlation. When yield is correlated with length of head, the differences are so small that definite conclusions cannot be drawn. Degrees of crowding have little effect on the correlation between yield and number of kernels. The same is true for yield and number of spikelets. There is a slight tendency shown for the correlation between yield and average weight of kernels to increase as crowding increases. There is a decided and significant increase in correlation between yield and number of kernels per spikelet as crowding increases. It seems that, up to a certain point, as crowding increases the correlation between yield and diameter of straw increases, and that beyond this point there is a decrease. There is an increase in correlation between yield and breaking strength of straw with increase in crowding, but a limit is reached, beyond which there is a decrease. Yield and weight of straw are highly correlated in the culms of oat plants, and the correlation is increased to a slight extent by crowding up to a certain point, beyond which there is a decrease. The diameter of straw is highly correlated with the breaking strength, but the least correlation exists when the crowding is least.

In every case when significant differences exist in the correlations between characters in plants grown under different conditions of crowding, there is an increase in correlation produced by more crowded conditions. In no case is the coefficient of correlation for the least crowded condition the largest, although the differences are often very small. There is, however, sometimes a decrease in correlation beyond a certain degree of crowding, in which case the coefficient for the intermediate degree of crowding is the highest.

It has been shown by this study that environmental conditions may influence the degree of correlation of certain characters to a marked extent. Such conditions may make of no significance the so-called varietal and other differences obtained by several investigators.

GENERAL DISCUSSION AND CONCLUSION

This study of oats has been taken up under four heads, as was outlined at the beginning of the paper. Various data have been presented and discussed under each of these heads, and summaries and conclusions have been made at the end of each division. The study has been pursued

with several purposes in view. One purpose has been to determine the averages, the amounts of variation, and the correlations that exist in various characters of oats. Another has been to determine the effects on these characters of various environmental influences. Under the latter head data on the question of methods to be pursued in biometrical work with cereals have been adduced.

Correlation has been carefully considered. This was deemed advisable because of the increasing use of, and attention given to, such studies. The correlations taken up have been principally of yield and average weight of kernels with various other characters. Webber (1906) has classified correlation into four groups — *environmental*, *morphological*, *physiological*, and *coherital*. It is very difficult to place the correlations here considered in this classification. It is certain that no cases of coherital correlations have been shown. Some of the correlations would probably be classed as environmental. But it has been shown that change in environment often produces radical changes in the correlation of certain parts. Environmental correlation, then, is not so simple a thing as might be supposed. Between morphological and physiological correlation there is no clear distinction, and it is probable that all the correlations here dealt with could be classified under either head.

The classification given by East (1908) is simpler in its main divisions these being *somatic* and *gametic*, but the subdivisions are not yet distinctly defined. The correlations treated here are somatic, but a further classification according to the subdivisions given would be difficult and perhaps unprofitable.

Correlations have been classified by Love and Leighty (1914) as *fluctuating* and *stable*, these divisions being based on the behavior of the relationship of the characters concerned when variation occurs in environmental conditions, such as exist in different years or in different locations. As the names indicate, the correlations of the first class may be made to vary considerably by changes in conditions, while those of the second class remain of about the same value or are stable in character. Both these classes of correlations are found among those reported in this paper.

The first division of this study is a comparison of biometrical constants determined for oat plants and for the culms of the same plants. From the results obtained it may be concluded that, for statistical work with oats, practically the same means and correlation coefficients will be obtained

whether plants are used as units or the culms of the same plants are used as units, but that these constants will be slightly greater for the latter method. The standard deviations and coefficients of variability will also be greater when culms are the units. The biometrical results obtained by the several investigators, whether they worked with culms or with plants, are, however, comparable, with slight reservation, as far as this factor affects the results.

The second division of this study is a biometrical comparison of varieties of oats. In this study, considerable difference is shown in average yield of culm per plant. This is due to the larger kernels produced by certain varieties, since the numbers of kernels and of spikelets are about the same for the different varieties. There are varietal differences in the height of culm. The average number of kernels per spikelet is greatest in the Sixty Day and smallest in the Early Champion variety. The proportion of straw to grain differs in the different varieties. Considerable difference is found in the amount of variability of different characters of the varieties. The greatest variability, in all characters but one, is found in the Welcome variety, while each of the others is least variable in one or more characters. The coefficients of correlation are usually fairly close together for the different varieties, but some differences occur that may be due to varietal causes.

The third division of this study is a comparison of biometrical constants determined for oat plants grown in hills and in drills. Regarding all characters here studied, the means are greater for plants grown in hills than for plants grown in drills. The least difference in the means occurs in the cases of average height of plant and average weight of kernels per plant. There is greater variability in average yield of culm per plant and average weight of straw in plants grown in hills, but much less variability for plants so grown in average height and average weight of kernels. The variability in number of kernels and number of spikelets is slightly greater for the plants grown in hills. Rather large differences occur in the same variety between the coefficients of correlation determined for the plants grown in the two ways. Whenever large differences in the coefficients of correlation occur, those for the plants grown in hills are always the smaller in amount. The differences due only to the growing condition may amount to more than any varietal differences observed in this work. The constants, then, obtained by different investigators

are comparable only in so far as the conditions of growth are comparable.

The fourth division of this study deals with the effect of different degrees of crowding on biometrical constants of oats. Oat plants grown in very crowded conditions produce but one culm to a plant, but, as more room is given, more than one culm are produced by many plants. The development of plants in most characters is greater in less crowded than in more crowded conditions. Variability decreases with increase in crowding for yield, number of kernels, number of spikelets, and breaking strength of straw; but for height the least variability occurs when crowding is least. In every case when significant differences exist in the correlations between characters in plants grown under different conditions of crowding, there is an increase in correlations produced by more crowded conditions, but there is sometimes a decrease beyond a certain degree of crowding. It has been shown that environmental conditions may influence the degree of correlation of certain characters to a marked extent. Such conditions of environment may make of no significance the so-called varietal and other differences obtained by several investigators.

ACKNOWLEDGMENTS

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LITERATURE CITED

Atkinson, Alfred

1912 A study of the correlation of characters of wheat. Thesis for degree of M. S. in Agr., Cornell University, 1912. (Unpublished.)

Davenport, Eugene

1907 Principles of breeding, p. 1–727.

East, E. M.

1908 Organic correlations. Amer. Breeders' Assoc. Ann. rept. **4**: 332–343.

Leighty, C. E.

1911 Correlation of characters in oats, with special reference to breeding. Amer. Breeders' Assoc. Ann. rept. **7** : 50–61.

Love, H. H., and Leighty, C. E.

1914 Variation and correlation of oats (Avena sativa). Part I. Studies showing the effect of seasonal changes on biometrical constants. Cornell Univ. Agr. Exp. Sta. Memoir No. 3 : 1–70.

Myers, C. H.

1911 Effect of fertility upon variation and correlation in wheat. Amer. Breeders' Assoc. Ann. rept. **7** : 61–74.

Noll, C. F.

1911 A study of variation and correlation in pure lines of wheat. Thesis for degree of M. S. in Agr., Cornell University, 1911. (Unpublished.)

Rietz, H. L., and Smith, L. H.

1910 On the measurement of correlation, with special reference to some characters of Indian corn. Univ. Illinois Agr. Exp. Sta. Bul. 148 : 291–316.

Roberts, H. F.

1911 Variation and correlation in wheat. Amer. Breeders' Assoc. Ann. rept. **7** : 80–109.

Waldron, L. R.

1910 A suggestion regarding heavy and light seed grain. Amer. nat. **44** : 48–56.

Webber, H. J.

1906 Correlation of characters in plant breeding. Amer. Breeders' Assoc. Ann. rept. **2** : 73–83.

JANUARY, 1914 CIRCULAR No. 21

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AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Plant Pathology

THE YELLOW-LEAF DISEASE OF CHERRY AND PLUM IN NURSERY STOCK[1]

VERN B. STEWART

Leaf blight, commonly known also as yellow leaf, or shot-hole, of plums and cherries, is one of the most important diseases attacking nursery stock. It was first reported in Europe in 1884 on *Prunus padus*, and has been common there on both sweet and sour cherries for the past twenty years. In America the disease has been reported on nearly all species of Prunus, both wild and cultivated. It occurs in all the nursery districts of the United States where cherry and plum stock is grown, and may be very destructive to nursery trees when weather conditions are favorable.

OCCURRENCE ON DIFFERENT HOSTS

Usually the disease occurs in abundance on the sweet cherry, *Prunus avium*, and on the wild chokecherry, *Prunus virginiana*. It is common on sour cherries, *Prunus cerasus*, *Prunus mahaleb*, and *Prunus pennsylvanica*, and on plums, *Prunus domestica*, *Prunus institia*, and *Prunus spinosa*. The leaves of *Prunus serotina* also are known to have been attacked.

In the nurseries of New York State the susceptibility of cherry and plum seedlings to the disease is of considerable importance. Mazzard cherry seedlings are very susceptible and often they are so badly defoliated that it is impossible to bud the trees. Mahaleb cherry stocks are attacked to some extent, but ordinarily the damage is less than on Mazzards. Myrobalan plum seedlings show a considerable degree of resistance and, at least in New York State, are seldom attacked.

The sweet-cherry varieties are more seriously affected than are the sour. Frequently, however, the disease is very destructive to all varieties of cherries and may cause a heavy loss of foliage. European plum varieties also may be defoliated completely by the disease during a season

[1] A report of work performed on the Stuart-Chase-Brown-Perkins industrial fellowship. The work has been made possible through the financial support and cooperation of the following nursery firms: C. W. Stuart & Co., Newark, New York; Chase Brothers Company, Rochester, New York; Brown Brothers, Rochester, New York; and Jackson & Perkins, Newark, New York.

of abundant rainfall (Fig. 1). Japanese plums are more resistant, and the disease is of little importance on these varieties (Fig. 2).

Figure 1

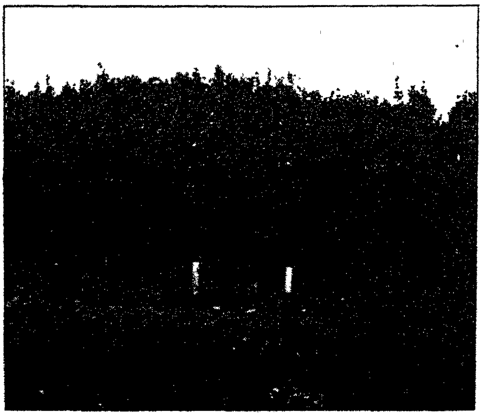

Figure 2

FIG. 1.— *European varieties of plums defoliated by the yellow-leaf disease*

FIG. 2.— *Japanese varieties of plums not affected by the disease*

SYMPTOMS

The leaves, the fruit, and the fruit pedicels may be attacked, but generally the lesions are confined to the foliage and their occurrence on the fruit is rather uncommon The disease is noticed first in the latter part of May or in early June. On certain hosts it becomes very noticeable because of the shot-hole appearance of the leaves. This condition is brought about by the dropping-out of the circular areas of affected tissue (Fig. 3). The shot-hole effect is commonest on plum varieties, in which the perforations may be so abundant that, owing to the dropping-out of the diseased areas, only remnants of the leaves are left. Infections on the Japanese plums are of a shot-hole nature, but it is believed that the larger percentage of the shot-hole effect on these varieties is caused by an insect; practically no defoliation occurs, as in the case of the European plum varieties.

On the leaves of cherries the diseased spots do not drop out so readily. They first appear on the upper side of the leaf as slightly discolored areas, usually not exceeding an eighth of an inch in diameter and more commonly about half that size. Later, after a period of seven to ten days, they become definite lesions, dark red or reddish brown in color. The infection may be confined to a small section of the leaf, but frequently the red spots, indicating the diseased areas, are thickly scattered over the entire leaf (Fig. 4). In the advanced stages a yellowing of the affected foliage may occur and the leaves may fall prematurely. The early loss of foliage affects the vigor of the trees; and the trees are poorly prepared to withstand the severe weather of the winter months, and begin growth the next spring with diminished vitality.

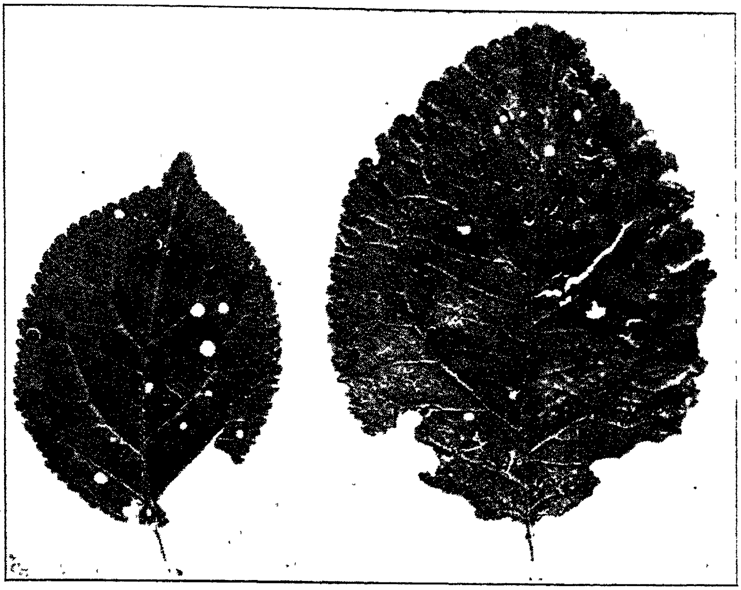

FIG. 3.— *Shot-hole effect on plum leaves*

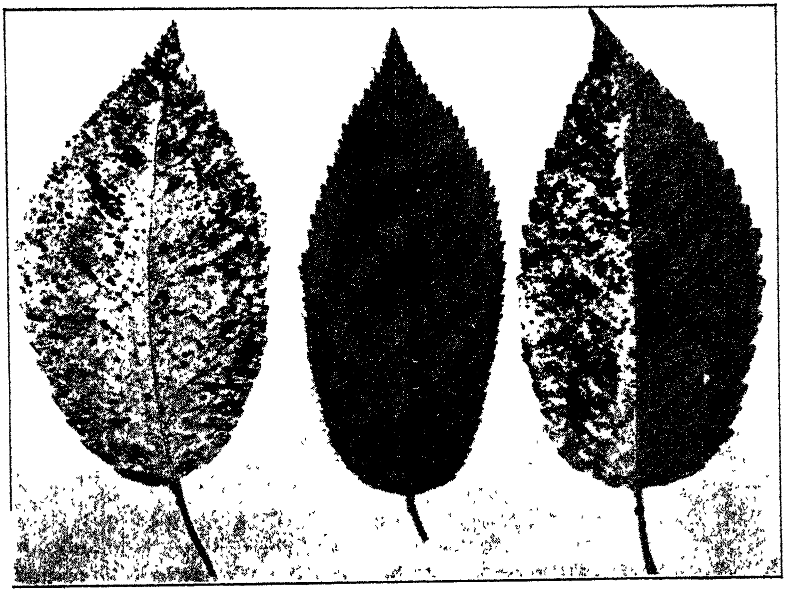

FIG. 4.— *Sweet-cherry leaves, showing the dark red spots and also the yellow discoloration*

The same yellowing sometimes appears on plum leaves, but never so abundantly as on sweet-cherry foliage.

Particularly during periods of wet weather, small white velvety pustules may be observed on the lower sides of the leaves, opposite the discolored spots. Occasionally these pustules appear also in the center of the lesions on the upper side of the leaf.

CAUSE[2]

The disease is caused by the organism *Cylindrosporium padi*, which belongs to a low group of plants known as fungi. Many of these forms are parasites, living on other plants. This fungous organism obtains its food and nourishment by means of minute vegetative, rootlike strands, called mycelium, which penetrate the leaves of the host plant and cause considerable damage to the tissues invaded. The conditions of temperature and the amount of rainfall that favor the growth of the trees are favorable also for the development of the fungus.

LIFE HISTORY

With the active growth of the fungus in the leaf tissue, the mycelial threads form a closely packed mass near the surface of the leaf, resulting in the formation of a fruiting body (Fig. 5). From the tips of certain strands of mycelium in the fruiting body there are developed minute, sickle-shaped bodies, known as spores. The number of spores produced is usually very great, and the spores are pushed out in such large numbers on the under surface of the leaf that they become visible. This accounts for the occurrence of the white pustules previously described. The spores, being very minute, are easily carried to the leaves by wind and rain, and are thus disseminated over a considerable distance. Falling on a leaf, the spore germinates, if moisture is present, by sending out a slender germ tube (Fig. 6). This tube penetrates the tissue of the leaf, and with continued growth the germ tube develops a mycelium with many branches. These branches extend between the cells of the leaf, often penetrating them or sending sucker-like branches into them. The affected areas become disorganized, and in this way the mycelium derives its nourishment from the leaf. The attacked cells turn brown, and as the mycelium extends further into the tissue the discoloration increases resulting in the formation of the reddish-colored spots, as previously described. When a number of germ tubes attack the same leaf, a large part of it becomes affected. The living substance is destroyed and the leaf drops prematurely, being no longer able to function in the manufacture of food for the tree.

Throughout the summer the disease continues to spread with each period of wet weather, and as the new foliage develops it is in constant danger of infection. Often the trees may be defoliated completely by the latter part of August and the ground may be covered with diseased leaves. It is in these old, affected leaves that the fungus lives over winter. By the formation of a special fruiting body within the leaf tissue the

[2] A description by B. B. Higgins of the perfect stage of the Cylindrosporium on *Prunus avium* was published in Science (n. s. 37:637–638. 1913). Doctor Higgins named the fungus *Coccomyces hiemalis* Higgins.

organism is able to withstand the severe cold weather of the winter months. During periods of abundant rainfall in the following spring, when the trees are developing the first new leaves, these specialized fruiting bodies —

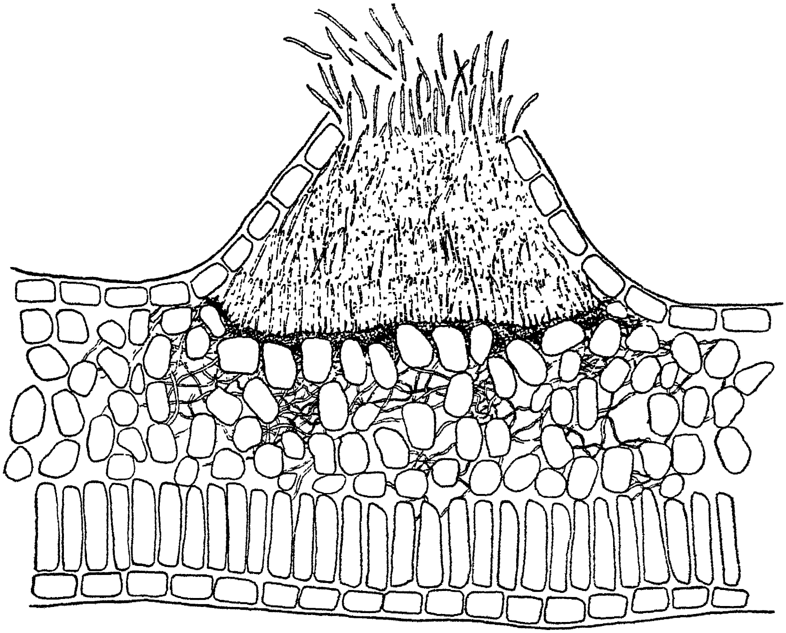

FIG. 5.— *Cross section of cherry leaf, through a mature fruiting body of the fungus*

known as perithecia — discharge large quantities of spores. Some of these spores are carried by the wind or by spattering drops of rain to the new foliage, where they produce the first infections of the year; and the characteristic diseased spots become apparent about seven to ten days later.

CONTROL

In the control of fungous diseases it becomes necessary to keep in mind the relation existing between the host and the fungus that causes the disease. In general, conditions of rainfall and temperature that influence the host plant affect also to some extent the activities of the fungus. Each rainy period of an ordinary summer season favors the growth of the trees, since sufficient moisture is supplied for their development. On the other hand, wet weather also affords necessary conditions for the fungus. Spores that are blown to other leaves are unable to germinate and produce infection unless moisture is present.

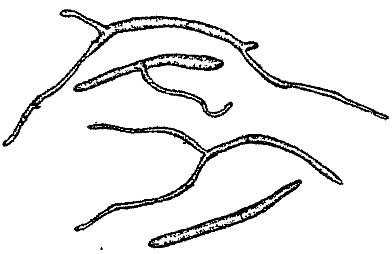

FIG. 6.—*Spores of the Cylindrosporium fungus, some of which have germinated*

The quantity of moisture required depends on the kind of fungus; but, in general, various fungi causing leaf diseases produce the greatest damage when damp, cloudy weather prevails for a period of twenty-four hours, or longer, after a rainfall. Drops of water falling on the leaves supply the spores with moisture for germination. The germ tube penetrates the leaf tissue within a period of a few hours and is soon able to obtain its nourishment from the affected tissue. To the naked eye, the first indication of the infections is the discolored areas that appear a week or so later.

After the spore has germinated and the germ tube has gained an entrance into the tissue, it is impossible to check the activities of the mycelium in the affected leaf. For control of the disease, therefore, it is necessary to check the fungus in its attacks before suitable conditions are afforded for the germination of the spores on healthy foliage.

If the old, diseased leaves that have remained on the ground throughout the winter are plowed under in spring before growth begins, a large source of early infection by the yellow-leaf fungus is eliminated. However, enough old leaves usually remain scattered about to enable the fungus to gain a foothold on the new leaves.

In order to prevent these attacks of the fungus and subsequent infection, the leaf surface must be covered with a fungicide, or a spray mixture which is highly poisonous to the fungus. When the spore germinates the germ tube comes in contact with the poison, is killed, and thus fails to produce an infection. Since the spores of the fungus are very minute — being about 1/500 inch in length — the fungicide must be sprayed on the foliage in the finest mist possible in order that the leaves may be completely covered and thus protected from the attacks of the fungus. When the mixture is applied with insufficient force it accumulates in large drops on the leaf surface, and under such conditions spores lying between the drops of spray mixture may germinate and produce infection without being affected by the poison. As previously stated, after the germ tube has entered the leaf tissue and the mycelium is established, the spray mixture on the outside has no effect on the fungus. The fungicide does not penetrate the leaf and kill the fungous mycelium.

Time for spraying

In preventing the disease through spraying, it is necessary to make the applications at such intervals as will afford the greatest protection to the foliage throughout the growing season. Since the disease appears rather early in the season, it is advisable, for the nursery stock at least, to make the first application when the first-year cherry and plum buds are about eight to ten inches in height. Subsequent sprayings should be made in accordance with the weather conditions that exist. As a general practice, about five to seven applications throughout the summer, at intervals of two weeks, will suffice to keep the disease in check. A thorough spraying will protect the leaves for a long time, but it will not be of any value to the foliage developed subsequently. If the entire tree is to be protected, the new leaves must be sprayed shortly after they appear and as long as growth continues. During the active period of such stock as the first-year cherry and plum buds, it is often necessary

to make two or three applications at shorter intervals owing to the rapid development of new leaves. On the other hand, with prolonged periods of dry weather the trees do not grow so rapidly and the time interval between certain of the sprayings may be somewhat lengthened. The growth of two-years-old stock is also influenced by similar conditions, and sprayings should be made according to the weather that prevails.

It is to be remembered, however, that in order to insure protection to new foliage the spraying mixture must be applied *before* the rains and not afterwards. *The fungicides are not washed off by the rains*, but, on the other hand, when the foliage is thoroughly covered the mixture acts as a preventive against the attacks of the germinating spores during damp, cloudy weather. Spraying should never be deferred nor discontinued for fear that the mixture will be washed off; it dries rapidly, and when dry a sufficient amount remains to afford protection against the fungus even after continued heavy rainfall.

Spray mixtures

Bordeaux mixture or lime-sulfur solution may be used for the control of the disease. Bordeaux mixture may be made by the grower, or it may be bought on the market in the prepared form known as bordeaux paste or powder. Homemade bordeaux is preferable, since it remains in suspension somewhat longer than the market mixture and it also has better sticking qualities when applied to the foliage. Bordeaux, while effective, may cause burning of plum foliage. The formula most commonly used for making bordeaux mixture is: 5 pounds of stone lime, freshly slaked, and 5 pounds of copper sulfate (blue vitriol), to 50 gallons of water.

In recent years lime-sulfur solution has been substituted for bordeaux mixture in the control of various fungous diseases. This solution also may be made by the grower; but, unless ample facilities are at hand, it is preferable, for nurserymen at least, to use commercial lime-sulfur solution which can be bought in a concentrated form. Lime-sulfur solution is easier to handle than is bordeaux mixture, but care must be taken not to apply the solution at such a strength that it will cause burning of the foliage. For cherries and plums, the yellow-leaf disease may be controlled, without injury to the foliage, by using lime-sulfur solution at a strength of 1 gallon to 50 gallons of water.

The addition of granulated iron sulfate prevents the danger of burning and also increases the sticking qualities of the solution, especially if it is applied at a low pressure or with a gas spraying machine. When added to lime-sulfur the iron sulfate turns the solution black in color; and when sprayed on the foliage, after three or four hours exposure to the air, the spray material oxidizes to a reddish brown or a rust color. When iron sulfate is used the following formula is desirable for spraying cherries and plums: lime-sulfur solution (testing 32° Baumé) 1 gallon, water 50 gallons, iron sulfate $1\frac{1}{2}$ pound.

Spraying machines

Without question the greatest problem confronting nurserymen in the control of nursery diseases is a satisfactory means of applying the spray mixture. An apparatus is desirable which will apply the spray with

sufficient force and with the least inconvenience. For small hand sprayers, of which there are several types on the market, the common knapsack sprayer is the most desirable machine for efficiency. Considerable objection is raised by laborers to this machine because of its weight and the difficulty of carrying it.

Numerous compressed-air hand sprayers (Fig 7) are in use, which are much lighter in weight than the knapsack sprayer; but none of these have been perfected to such a degree that they maintain a constant desired pressure. There is too great a decrease in pressure as the tank is being emptied. Compressed-air machines, however, are practicable if care is taken to pump them up frequently in order to maintain a good pressure.

FIG. 7.— *Compressed-air hand sprayer. Photograph by D. Gunn*

The power sprayers used by some nurserymen have been of various kinds and as a whole are not entirely satisfactory. It has been difficult to construct a machine that could be transported over tall stock and at the same time be practicable for general use.

Without question a traction sprayer might be constructed so that it would be suitable for nursery work; but the greatest criticism of those that the writer has seen is that they have been built for use with one horse. It does not seem advisable to use a one-horse sprayer in large stock. With rows only three or three and one half feet apart, the shafts, in order to provide room for a horse of sufficient draft, must be set so far apart that they bruise and injure the trees. This is especially true when driving over rough and unlevel ground.

The construction of a two-horse machine is even more difficult, and those in use might be considerably improved. A sprayer of this type should be built to spray at least four rows of large stock, should be easy to transport, and should be equipped with a device that will furnish the necessary pressure for spraying. The power for spraying machines has usually been supplied by traction, gasoline engines, compressed-air tanks, or compressed carbonic acid gas. Since it is necessary for large nursery stock that a machine be built to order, the expense is rather high for the small grower. Under such conditions it is well to depend on hand sprayers for spraying large nursery trees, while a traction machine similar to that used for potato-spraying is very desirable for smaller stock.

In a large nursery where there are acres of large trees, it is preferable to have a machine that will permit the spraying to be done with con-

siderable rapidity and as economically as possible. The large two-horse machine appears to be the logical means of meeting these requirements.

For the past three years the writer has seen in operation a nursery sprayer (Figs. 8 and 9) that sprays four rows and clears all stock not exceeding six feet in height. The machine straddles two rows, and is operated with comparative ease with two horses. Two 50-gallon steel tanks are used for retainers of the spray mixture, and the power is furnished by compressed carbonic acid gas. The gas is obtained in steel drums and the spraying may be done with any pressure desired.

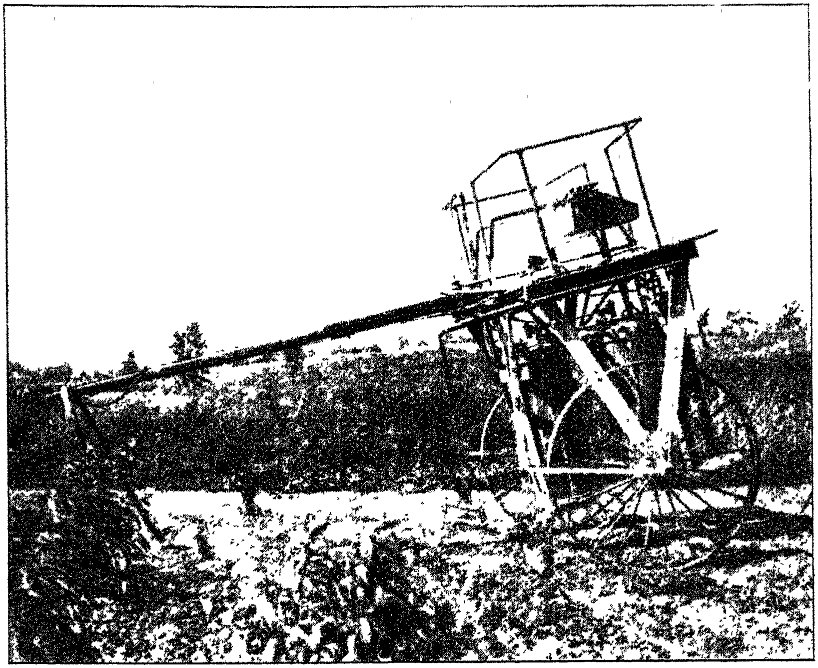

FIG. 8.—*A two-horse gas-power sprayer for spraying all stock below six feet in height. Photograph by D. Gunn*

Usually, for general nursery spraying with two nozzles to each row, spraying four rows at a time, a constant pressure of 100 pounds is sufficient. One drum containing 50 pounds net of gas, costing $2.50, will furnish power for spraying practically 500 gallons of spray mixture.

The most serious objection to the use of carbonic acid gas for power is the fact that it acts on lime-sulfur when this solution is used for spraying, and precipitates the sulfur. The precipitated-sulfur solution is less effective than the ordinary solution as an insecticide when used for San José scale or other scale insects. Therefore a gas machine should never be used for spraying lime-sulfur during the dormant season or before the leaves appear in the spring. Bordeaux mixture and arsenate of lead are not appreciably affected by the gas.

On the other hand, as a summer spray in the control of fungous diseases such as yellow leaf of cherry and plum, the value of lime-sulfur is not affected by the gas The precipitated-sulfur solution is just as effective in keeping the fungus in check as when the solution is applied by means of other power. The sticking qualities of the solution are greatly increased by the addition of $1\frac{1}{2}$ pound of iron sulfate to the 1–50 lime-sulfur solution, previously discussed.

The machine illustrated in Figs. 8 and 9 has been in use for three seasons, and during the past summer a machine of a similar type,

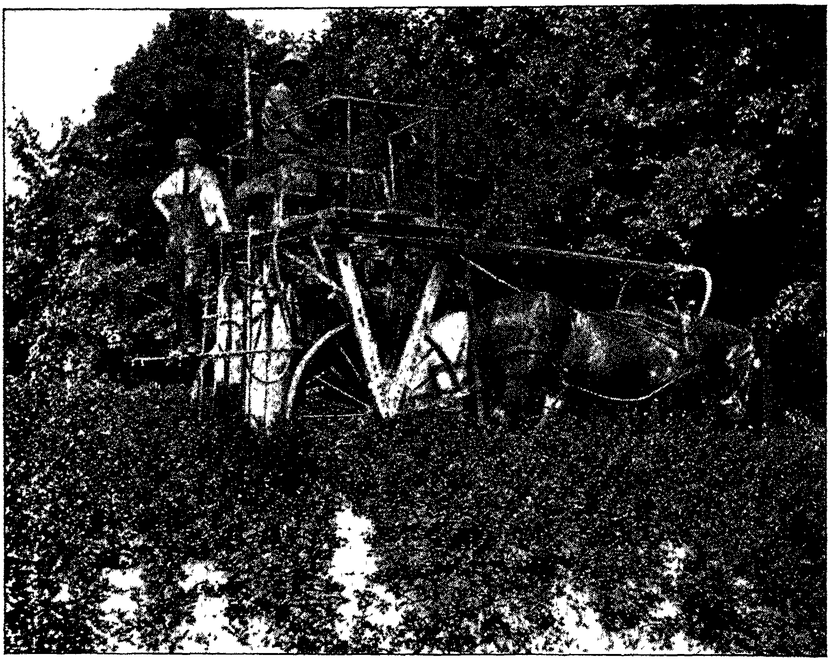

FIG. 9.— *The gas-power sprayer in operation. Photograph by D. Gunn*

but somewhat improved, was used in another large nursery. Where these machines are employed all the spraying has been under the direction of the writer, and in general the results have been satisfactory.

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Department of Farm Management

WHOLESALE PRICES OF APPLES AND RECEIPTS OF APPLES IN NEW YORK CITY FOR TWENTY YEARS[1]

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A comparison of prices of farm products as a whole for seventy-three years is given in Bulletin 341 of this Station. The prices of various products do not rise and fall together; at one time a certain product may rise more rapidly in price than other products, at another time it may not rise so fast. The prices of products are to some extent an indication as to which products are being over- or under-produced.

The average prices in different months are one of the factors that help in determining the best time for selling. The cost of storage, the probable shrinkage in the particular storage, extra cost of handling, need for the money, and other factors must also be considered. The changes in prices of different varieties may be of some value in determining what varieties should be planted. This circular gives information as to the receipts of apples in New York City for different years and for different months, the average prices by years and a comparison of the rise in price with the changes in price of other products, the average prices by months, and the average prices of different varieties of apples. It is hoped that these figures may be of some help to farmers who are interested in apples.

How the figures were obtained. The figures used in this publication are those of the New York market. They were obtained in the following ways: the receipts of apples were obtained from the statistician of the New York Mercantile Exchange; the price figures, representing wholesale prices on the New York market, were obtained from weekly quotations in the Rural New-Yorker; missing figures were supplied from the Tribune Farmer, including the record for the season of 1903–1904.

The quotations are made up by a representative of the journal whose business it is to cover the market and make a record of actual sales. Probably seventy-five per cent of the business done in apples is covered. The daily quotations are averaged in order to obtain weekly figures giving the high and the low range, and these figures are published. In this work, weekly quotations have been averaged in order to obtain figures representing the range in prices for the month. The average price for the month has then been computed and average figures have been used in all calculations.

[1] The author is indebted to Dr. G. F. Warren for suggestions and criticisms in the preparation of this circular.

TABLE 1. MONTHLY AND YEARLY RECEIPTS OF APPLES IN NEW YORK CITY (IN BARRELS*), 1893–1913

	August	September	October	November	December	January	February	March	April	May	June	July	Total
1893–1894	4,632	20,461	57,068	66,160	25,678	18,692	15,462	12,451	8,845	5,114	971	1,430	237,264
1894–1895	17,046	33,800	125,000	159,527	58,419	33,032	27,942	36,522	24,608	10,442	2,193	20,177	518,708
1895–1896	33,510	75,394	152,419	164,463	110,638	50,327	58,782	45,293	30,209	13,955	1,497	12,017	718,504
1896–1897	51,947	188,135	263,491	273,052	165,494	115,096	134,113	125,915	74,936	24,654	9,683	19,813	1,446,350
1897–1898	38,713	71,433	203,538	196,477	81,695	70,619	62,560	71,913	47,521	25,532	7,046	5,306	882,473
1898–1899	30,428	76,807	161,876	117,608	89,251	49,578	37,323	36,752	33,148	16,368	1,547	11,270	661,962
1899–1900	47,918	102,955	206,216	185,785	113,277	75,164	72,156	60,991	38,498	16,528	2,860	3,517	925,165
1900–1901	23,116	82,426	176,411	189,521	101,193	99,087	69,548	69,017	55,282	25,959	3,507	5,443	901,410
1901–1902	18,379	53,611	127,191	106,371	57,021	51,597	30,013	36,671	43,463	18,328	5,171	10,576	564,392
1902–1903	68,007	154,475	287,936	255,942	166,971	130,626	122,687	160,567	96,626	62,503	33,665	23,721	1,563,726
Yearly average for ten years	33,370	85,950	176,115	171,491	96,964	69,385	63,659	65,632	45,314	21,968	6,814	11,337	847,990
1903–1904	95,142	246,684	435,950	399,130	193,206	144,919	165,102	166,698	108,761	56,203	31,811	8,016	2,051,622
1904–1905	85,332	284,112	309,135	337,336	168,721	143,071	122,565	193,460	130,367	70,923	20,437	22,236	1,887,695
1905–1906	143,052	252,056	367,638	281,482	152,945	119,309	82,084	80,466	49,034	27,802	10,987	7,688	1,574,543
1906–1907	174,637	255,600	478,323	413,566	223,554	223,469	145,847	173,133	87,412	39,442	12,594	1,917	2,229,494
1907–1908	60,488	137,729	350,529	364,490	171,099	168,649	117,938	100,210	108,194	75,719	33,162	13,839	1,762,046
1908–1909	121,641	310,289	447,895	337,580	217,601	137,683	92,688	87,198	61,486	32,369	11,837	5,470	1,863,737
1909–1910	64,305	183,892	393,288	406,772	248,797	131,709	138,119	162,011	98,764	51,063	19,548	6,403	1,904,671
1910–1911	78,678	196,597	538,630	416,374	208,490	127,015	115,654	105,385	74,361	48,107	23,036	5,550	1,937,883
1911–1912	75,922	199,039	320,569	314,330	301,257	176,639	171,219	138,045	102,727	52,757	22,664	5,335	1,880,503
1912–1913	41,335	171,798	636,626	464,450	223,096	201,154	193,846	217,240	191,250	93,969	45,177	16,706	2,196,647
Yearly average for ten years	94,053	223,780	427,858	373,551	210,877	157,362	134,506	148,385	101,236	54,835	23,125	9,317	1,958,884

* Boxes have been reduced to barrels, three boxes to a barrel.

Receipts of apples in New York. The monthly and the yearly receipts of apples in New York for twenty years are given in Table 1. The average receipts per year for the first ten years were 847,996 barrels. For the second ten-years period the receipts were 1,958,884 barrels. This is an increase of 131 per cent.

During the ten years 1900 to 1910, the population of the area now making up New York City increased 39 per cent. The population of the New York metropolitan district, including New York and thirty cities and towns surrounding it, increased 46 per cent. We do not know whether or not New York is acting as a distributing center more than formerly, but there seems to be no doubt that the average person is using very many more apples than formerly. Apparently 59 per cent more apples for every person are being used.

Distribution of receipts by months. The receipts are heaviest in October and November, over 40 per cent of the receipts for the entire year going on the market during those months (Table 2) There has been little change in the proportion of receipts for each month during the two ten-years periods.

TABLE 2. AVERAGE MONTHLY RECEIPTS OF APPLES IN NEW YORK

Month	1893 to 1903		1903 to 1913	
	Average receipts	Percentage of total	Average receipts	Percentage of total
August	33,370	3.94	94,053	4.80
September	85,950	10.14	223,780	11.42
October	176,115	20.77	427,858	21.84
November	171,491	20.22	373,551	19.07
December	96,964	11.43	210,877	10.77
January	69,385	8.18	157,362	8.03
February	63,659	7.51	134,506	6.87
March	65,632	7.74	148,385	7.57
April	45,314	5.34	101,236	5.17
May	21,968	2.59	54,835	2.80
June	6,814	0.80	23,125	1.18
July	11,337	1.34	9,317	0.48

Average prices by months. The average prices of apples by months are shown in Table 3. There is a gradual rise in the price of apples from August until May, with a slight drop in June. During the last ten years the prices for August and September have been relatively better than formerly.

Average prices by years. The average price of apples for the ten years from 1893 to 1903 was $2.62; for the next ten years it was $2.87 (Table 4). The average price varied from $1.41 in 1896 to $3.72 in 1901. In eight of the twenty years the average price was above $3 a barrel.

Comparative increase in prices of apples and other farm crops. In the last ten years apples show an increase in price of 9½ per cent as compared with the previous ten years. In the same period the price of cotton increased 64 per cent, corn 42, hay 33, oats 38, potatoes 28, and wheat 37 per cent (Table 5).

TABLE 3. AVERAGE PRICES PER BARREL OF APPLES IN NEW YORK BY MONTHS FOR TWENTY YEARS*

	August	September	October	November	December	January	February	March	April	May	June
1893–1894	$2 18	$2 45	$2 65	$3 10	$3.88	$4 56	$5 10	$4 37	$5.00	$4 98	..
1894–1895	1 83	1 95	2.17	2.34	2 58	3 00	3.84	3.69	4.00	3 52	....
1895–1896	1.56	1 59	1 99	2.13	2 28	2 30	2.64	2 95	3.19	3.16	$3.25
1896–1897	1 49	1 32	1 31	1 20	1.20	1.40	1 53	1 56	2.22	2 60	2 89
1897–1898	1 98	2 11	2.22	2.54	2 99	3 27	3 23	3 16	3.08	3 26	3.47
1898–1899	2 13	2.43	2.27	3.48	3 93	4 12	4 00	4.61	4 33	3 92	4 14
1899–1900	1 69	1 81	1 78	2.05	2 51	2 61	2 91	3 38	4 19	4.07	3 37
1900–1901	1 63	1 84	1.87	2.32	2 70	2 74	3 11	3 23	3 36	3 52	4.31
1901–1902	3 08	3.23	3.80	4 45	4.10	2 59	3 21	3 68	3 87	3 69	3.37
1902–1903	2 00	1 72	1 99	1.77	1.76	2 56	2 35	2 37	2 37	2 50	2.56
1903–1904	2.38	2 02	2 18	2.42	2.36	2.40	2 85	2 67	2 66	2.66	2 55
1904–1905	2.15	1 85	1.75	1 95	2 19	2 22	2.34	2 41	2.20	2 72	3 31
1905–1906	2 54	2 56	2 90	3 32	3.53	3 50	4.51	4 77	5.10	5 24	5 48
1906–1907	2 67	2 48	2.34	2 38	2 19	2.26	2 80	3 82	3 94	5 23	5.64
1907–1908	..	2 91	2 94	3 06	2 95	3 08	3 71	3.04	3 33	3 05	1.93
1908–1909	2 93	2 59	2 75	3 00	3 58	4 11	4 33	4 25	4 29	4 60	4 93
1909–1910	3 15	3 31	3 01	3 27	3 20	3 00	3 23	3 10	3.14	3 58	3.88
1910–1911	3 17	3.27	3 28	3 40	3.37	3 77	4 19	4.48	4.85	4 81	4 33
1911–1912	2 34	2 22	2.51	2 63	2 59	2 87	2 66	3 03	3.44	3.66	3.11
1912–1913	..	2 66	2 48	2 40	2.38	2 53	2 69	2 44	2.69	4.04	4.09
Yearly average for twenty years	$2.27	$2 32	$2.41	$2.66	$2.81	$2.94	$3 26	$3.35	$3.56	$3.74	$3.70
Yearly average 1893 to 1903	1 96	2 05	2.20	2.54	2 79	2 91	3.19	3.30	3.56	3.52	3.42
Yearly average 1903 to 1913	2 67	2.59	2.62	2.78	2.83	2.97	3.33	3.40	3.56	3.96	3.92

* Sixteen varieties are considered in this table — all that were quoted consistently enough to be worthy of consideration. They are: Alexander, Fall Pippin, Fameuse, Gravenstein, Maiden Blush, McIntosh, Oldenburg, Twenty Ounce, Baldwin, Ben Davis, Esopus Spitzenburg, Northern Spy, Rhode Island, Russet, Tompkins King, Pound Sweet. In the statement of receipts the number of barrels of each variety is not given. Each variety has equal weight for the months for which it is quoted. This allows for some error, but is the most nearly accurate way of figuring.

TABLE 4 AVERAGE PRICES OF APPLES IN NEW YORK FOR TWENTY YEARS*

	Total receipts (barrels)	Total value	Average price per barrel	
1893–1894	234,863	$ 805,873	$3 43	2.62
1894–1895	526,338	1,368,716	2 60	
1895–1896	736,487	1,627,907	2.21	
1896–1897	1,426,546	2,018,411	1 41	
1897–1898	877,077	2,336,934	2 66	
1898–1899	650,686	2,116,021	3.25	
1899–1900	921,648	2,147,728	2.33	
1900–1901	895,967	2,238,004	2.50	
1901–1902	553,816	2,057,679	3.72	
1902–1903	1,540,005	3,196,294	2.08	
1903–1904	2,043,606	4,880,324	2 39	2.87
1904–1905	1,865,459	3,895,384	2 09	
1905–1906	1,566,855	5,176,749	3 30	
1906–1907	2,227,577	5,889,810	2 64	
1907–1908	1,687,719	5,150,687	3 05	
1908–1909	1,858,267	5,992,356	3 22	
1909–1910	1,898,268	6,045,390	3.18	
1910–1911	1,932,327	6,904,624	3.57	
1911–1912	1,875,168	5,028,725	2.68	
1912–1913	2,438,606	6,320,766	2.59	

* The total value for the year is obtained by multiplying the receipts for each month (Table 1) by the average price for that month (Table 3). The total value divided by the total receipts gives the average price. This is the most nearly accurate method of determining the price with the figures available. No price was obtained for July, therefore the receipts for July were omitted. This was necessary also for June 1893–1894, June 1894–1895, August 1907–1908, and August 1912–1913.

TABLE 5. COMPARATIVE INCREASE IN PRICE OF APPLES AND OTHER CROPS*

	Percentage increase in price for last ten years as compared with previous ten years
Apples	9.5
Cotton	64.1
Corn	41.9
Hay	33.4
Oats	37.7
Potatoes	28.2
Wheat	36.5

* The prices of other crops are farm prices taken from the Yearbook of the United States Department of Agriculture.

The very great increase of 131 per cent in the receipts of apples is probably the cause of the relatively small increase in their price.

Comparative prices of different varieties of apples. The Ben Davis and the Esopus Spitzenberg have dropped in price, while other varieties, including some of the early varieties, have risen (Table 6). The average prices for each variety by months are shown in Table 7.

TABLE 6. PRICES OF DIFFERENT VARIETIES BY YEARS, AND PERCENTAGE OF INCREASE IN THE LAST TEN YEARS OVER THE PREVIOUS TEN YEARS*

	Alexander August-November	Fall Pippin August-November	Fameuse October-December	Gravenstein August-October	Maiden Blush August-October	McIntosh September-December	Oldenburg August-October	Twenty Ounce August-November	Baldwin September-June	Ben Davis October-June	Esopus Spitzenburg October-May	Northern Spy October-June	Rhode Island September-May	Russet March-June	Tompkins King September-April	Pound Sweet September-December
1893-1894	.	2.54	3.28	2.64	2.40	. .	2.62	2.81	3.90	3.05	5.04	3.80	3.39	4.44	4.02	. . .
1894-1895	2.75	2.02	2.45	1.84	2.01	.....	1.84	2.12	2.78	4.00	3.96	2.86	3.01	3.07	2.56	
1895-1896	2.32	1.73	3.16	1.86	1.62	..	1.66	1.71	2.37	2.76	1.80	2.20	2.47	2.73	2.33	..
1896-1897	1.57	1.30	1.49	1.53	1.12	.....	1.43	1.33	1.53	2.71	1.82	1.93	1.69	2.08	1.47	1.18
1897-1898	2.25	1.97	...	2.07	2.20	.....	2.24	1.96	2.72	3.13		2.83	2.87	2.88	3.15	
1898-1899	2.47	2.31	3.67	2.09	2.56	.. ..	2.25	. . .	3.72	4.12	. ..	3.63	4.17	3.49	3.20	. .
1899-1900	2.03	1.53	2.35	2.02	1.69	.....	1.68	1.73	2.77	3.06	3.51	2.71	2.55	3.10	2.51	. .
1900-1901	1.92	1.63	2.47	2.00	1.73	...	1.95	1.75	2.70	2.87	3.78	2.97	2.49	3.04	2.73	1.93
1901-1902	3.52	3.37	4.06	3.01	...	.. ..	3.30	3.52	3.46	3.52	4.46	3.20	3.65	2.92	4.17	2.91
1902-1903	2.32	1.67	1.76	1.87	1.71	.. ..	2.85	1.80	1.99	2.24	2.73	2.07	2.14	2.17	2.24	1.50
1903-1904	2.93	1.93	2.77	2.52	1.96	.....	2.35	2.06	2.23	2.33	2.90	2.59	2.32	2.30	2.80	1.86
1904-1905	2.26	1.85	2.04	1.98	1.76	3.00	1.93	2.05	2.07	2.19	2.54	2.42	1.94	2.52	2.52	1.50
1905-1906	2.31	2.55	3.06	2.78	2.46	3.90	2.74	2.84	3.88	4.02	4.25	4.64	3.79	4.55	4.15	2.75
1906-1907	2.93	2.39	2.76	2.54	2.42	3.25	2.62	2.24	3.26	3.29	3.24	3.29	2.94	4.09	3.03	
1907-1908	3.87	2.70	3.00	2.73	2.88	3.65	3.76	2.99	2.86	2.62	3.30	3.10	3.14	1.98	3.24	2.62
1908-1909	3.10	2.73	2.96	2.80	2.57	3.75	2.65	2.74	4.16	3.26	4.14	4.36	3.61	3.52	3.71	2.12
1909-1910	4.04	3.31	3.71	2.75	2.62	3.95	3.16	3.13	3.19	3.06	2.89	3.17	3.44	2.71	3.43	.. ..
1910-1911	3.71	3.12	3.37	3.05	3.36	3.89	3.05	3.48	4.02	3.60	.... .	4.42	4.20	3.76	3.54	. .
1911-1912	2.98	2.34	*	2.32	2.06	3.00	2.45	2.57	2.61	2.41	3.14	3.25	2.86	..	2.83	. .
1912-1913	3.01	2.59	. .	2.69	2.32	3.22	2.46	2.56	2.66	2.46	3.25	3.35	2.71	2.42	2.55	2.10
Average for twenty years	2.75	2.28	2.84	2.35	2.18	....	2.45	2.39	2.94	3.04	3.34	3.14	2.97	3.04	3.01	2.05
Average 1893 to 1903	2.35	2.01	2.74	2.09	1.89	.....	2.19	2.08	2.79	3.15	3.39	2.83	2.84	3.00	2.84	1.88
Average 1903 to 1913	3.11	2.55	2.96	2.62	2.44	3.51	2.72	2.67	3.09	2.92	3.29	3.46	3.10	3.09	3.18	2.16
Percentage increase in last ten years over previous ten years	32.3	26.9	8.0	25.4	29.1	.....	24.2	28.4	10.8	—7.3	—2.9	22.3	9.2	3.0	12.0	14.9

* Blanks indicate no quotations for that year.

TABLE 7 AVERAGE PRICES OF VARIETIES BY MONTHS

Variety	August	September	October	November	December	January	February	March	April	May	June
1893-1894 to 1902-1903											
Alexander	$2.13	$2.39	$2.77	$2.75							
Fall Pippin	1.56	1.89	2.09	1.98							
Fameuse			2.47	2.92	$3.47						
Gravenstein	1.82	2.16	2.03								
Maiden Blush	1.64	1.86	2.08								
McIntosh											
Oldenburg	1.99	2.01	1.62								
Twenty Ounce	1.83	1.93	2.05	2.64							
Baldwin		1.75	1.85	2.30	2.61	$2.75	$3.03	$3.15	$3.45	$3.56	$3.57
Ben Davis			2.41	2.46	2.65	2.67	2.88	3.27	3.53	3.56	3.42
Esopus Spitzenberg			2.91	3.03	3.34	3.13	3.61	3.68	3.90	3.29	
Northern Spy			1.89	2.32	2.47	2.72	3.00	3.06	3.73	3.40	3.05
Rhode Island		1.90	2.01	2.43	2.75	2.91	3.12	3.30	3.76	3.34	
Russet								2.98	2.83	3.07	3.10
Tompkins King		2.31	2.48	2.99	2.99	2.96	3.38	3.03	1.84		
Pound Sweet		2.75	2.00	1.50	1.25						
1903-1904 to 1912-1913											
Alexander	3.08	3.18	3.18	3.30							
Fall Pippin	2.43	2.43	2.52	2.87							
Fameuse			2.82	3.01	2.56						
Gravenstein	2.48	2.62	2.64								
Maiden Blush	2.23	2.41	2.42								
McIntosh		2.93	3.58	3.64	3.70						
Oldenburg	2.63	2.72	2.91								
Twenty Ounce	2.46	2.57	2.66	2.96							
Baldwin		2.08	2.16	2.39	2.54	2.80	3.19	3.40	3.64	4.07	4.03
Ben Davis			2.44	2.41	2.29	2.47	2.71	3.21	3.25	3.80	3.94
Esopus Spitzenberg			2.44	2.79	2.87	2.97	3.57	3.57	3.52	4.02	
Northern Spy			2.17	2.69	2.77	2.87	3.44	3.60	3.85	4.33	4.51
Rhode Island		2.09	2.31	2.69	2.96	3.09	3.24	3.47	3.90	4.08	
Russet								2.79	2.79	3.29	3.44
Tompkins King		2.61	2.79	2.99	3.13	3.27	3.58	3.44	3.30		
Pound Sweet		1.68	2.02	2.34	2.37						

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17 The formation of cow-testing associations
18 Milking machines: their sterilization and their efficiency in producing clean milk
19 Late blight and rot of potatoes
20 The fire blight disease and its control in nursery stock
21 The yellow-leaf disease of cherry and plum in nursery stock
(Extension Circular No. 1) A plan for a rural community center

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AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Soil Technology

OUTLINE OF THE FUNCTION AND USE OF COMMERCIAL FERTILIZERS

ELMER O. FIPPIN

In the selection of a commercial fertilizer, four primary conditions must be considered. These are (1) the composition of the plant, (2) the composition of the soil, (3) the nature and condition of the soil, and (4) the nature and composition of fertilizer materials. The third factor most often determines the need for fertilizer.

PLANT-FOOD ELEMENTS

All plants use at least ten elements as food. These are carbon, hydrogen, oxygen, nitrogen, potassium, phosphorus, sulfur, calcium, magnesium, and iron. In addition there are three other elements that may be used by plants. These are sodium, chlorin, and silica.

The first three elements make up 90 to 98 per cent of green plants. Nitrogen forms .2 to 1.5 per cent. The remaining elements make up 1 to 8 per cent of the plant substance, and are termed the ash constituents.

The carbon, hydrogen, and oxygen are obtained from the air and from water. There is no lack in the supply of these elements. Nitrogen, which makes up three quarters of the atmosphere, is not used in this simple form. It must be in some combined form, preferably nitrate (NO_3) or ammonia (NH_3), and is absorbed by the roots of plants from the soil. The available supply of combined nitrogen in the soil may be deficient.

The mineral elements are obtained from the rock particles that make up the greater part of soils. These various mineral elements are used in different quantities by the plant. Different plants also use different proportions of the mineral elements.

The quantities of the primary plant-food elements obtained from the soil, as found in some common crops, are as follows:

TABLE 1. COMPOSITION OF CROPS

Crops	Yield per acre	Nitrogen (pounds per acre)	Potassium (pounds per acre)	Sulfur (pounds per acre)	Phosphorus (pounds per acre)	Calcium (pounds per acre)	Magnesium (pounds per acre)
Corn grain...	50 bushels	50 0	9.5	5 0	8 5	1 0	3.0
Corn stover..	1.5 ton....	24.0	26.0	2.0	3.0	10.0	5.0
Wheat grain...	25 bushels.	35.5	6.5	4.0	6.0	1.0	2.0
Wheat straw..	1 ton.....	10.0	10.5	3.0	2.0	4.0	1.5
Oats grain ...	45 bushels	25.0	7.0	3.0	6.5	1.5	2.0
Oats straw....	1¼ ton....	12.0	27.0	3.0	3.0	6.0	3.0
Clover hay....	2 tons....	80.0	60.0	12.0	10.0	45.0	17.0
Alfalfa hay...	3 tons....	140.0	50.0	18.0	14.0	67.0	24.0
Potatoes....	200 bushels	44 0	60.0	7 5	9 0	3.5	4.0
Apples, fruit..	300 bushels.	24 0	28.5	1.0	2.5	1.0	2.0
Apple leaves	2 tons...	30.0	27.0	2 0	3 5	50.0	13.0

PLANT-FOOD IN THE SOIL

The soil material is the source of all the plant-food elements except carbon, hydrogen, and oxygen. In comparison with the amounts of the plant-food elements removed by any crop in a single year, the amount of plant-food in the soil is large.

TABLE 2. COMPOSITION OF SOILS PER ACRE-FOOT

	Nitrogen (pounds)	Potassium (pounds)	Sulfur (pounds)	Phosphorus (pounds)	Calcium (pounds)	Magnesium (pounds)
A normal soil.	6,000	30,000	1,200	1,600	24,000	15,000
Tompkins county, New York, Volusia silt loam.....	5,000	53,000	...	1,800	5,000	6,500
Tompkins county, New York, Volusia loam......	5,250	50,000	......	1,500	12,500	16,000
Tompkins county, New York, Dunkirk clay loam.	7,000	60,000	.....	3,000	22,000	10,000
Ohio soils, average northeast section	4,000	3,000	1,000	1,800	17,000	24,000

TABLE 3. MAXIMUM NUMBER OF CROPS THAT COULD BE PRODUCED BY THE QUANTITY OF EACH OF THE PRIMARY PLANT-FOOD ELEMENTS IN AN ACRE-FOOT OF NORMAL SOIL

Crop	Yield per acre	Nitrogen	Potassium	Phosphorus	Sulfur	Calcium	Magnesium
Corn	50 bushels grain and stover	80	860	133	172	2,182	1,875
Wheat.. ..	25 bushels grain and straw	133	1,765	200	171	4,800	4,300
Oats..... ..	45 bushels grain and straw	162	882	168	200	3,200	3,000
Red clover hay	2 tons	75	500	160	100	533	882
Alfalfa hay	3 tons	45	600	115	70	373	625
Potatoes.	200 bushels, 2 tons tops..	136	500	177	160	6,860	3,750
Apples.. ..	300 bushels, 2 tons leaves	111	550	266	400	470	1,000

The figures in Table 3 show the practical impossibility of exhausting the potassium and lime elements by cropping. They suggest that systems of farming which neglect the supply of nitrogen make that element the first controlling factor in yields. They also show that, in a very few decades of cropping, the supply of phosphorus and sulfur may exert a controlling influence on yields by absolute exhaustion in the surface soil. When the *root-feeding* zone is maintained at *three feet* by good drainage, the figures for the mineral elements are tripled, which defers almost indefinitely the absolute exhaustion of any of these elements from the root zone. The tables given above also emphasize the importance of factors that increase the availability of the food elements in the soil.

There are abnormal soils that are much less well supplied with some of the important plant-food elements, especially nitrogen, phosphorus, and sulfur, than are the average.

The amount of each plant-food element in the crop must be considered, but more important is the relative *total and available* supply of these in the soil. Because of the facts shown in the above tables, the chemical analysis of the soil is not usually an adequate guide to the need of any plant-food element in the soil. While analysis indicates the total supply of plant-food in the soil, it cannot adequately indicate its availability.

The plant-food in the subsoil, which is nearly as rich as the topsoil, may be relied on for crop production if the physical conditions in the subsoil are favorable to root penetration.

Nitrogen is present in soil chiefly in combination with organic matter. If a good stock of organic matter is maintained in the soil, the total supply of nitrogen is likely to be adequate. By means of leguminous plants that have nodules on their roots, and by means of a favorable condition of the soil, a large quantity of nitrogen may be obtained from the atmosphere and placed in the soil in form for future crops.

The basic elements of plant-food — calcium and magnesium — will be adequate for plant-food purposes if they are present in sufficient quantity to keep the soil alkalin (sweet).

CONDITIONS OF THE SOIL FAVORING THE AVAILABILITY OF PLANT-FOOD

The availability of the normally large stock of plant-food in the soil is primarily dependent on the following conditions:

1. A good tilth, or physical condition of the soil
2. Good drainage, including that of the subsoil to a depth of three feet
3. A good stock of decaying organic matter
4. Sufficient lime carbonate to maintain a neutral or a sweet soil
5. A uniformly moist condition of the soil
6. A moderately warm temperature
7. Good ventilation, which is aided by tillage
8. The presence of a favorable and efficient flora of micro-organisms in the soil

FERTILIZERS

Due either to a lack of the total required quantity of some one or more plant-food elements or to the low availability of such elements, the growing crop may need to be artificially fed by the use of commercial fertilizers. These are selected because of:

1. The presence and availability of one or more plant-food elements

2. The relative cost of the plant-food in the fertilizer
3. The composition of the fertilizer with reference to the needs of the soil and the plant
4. The possible residual effects of the fertilizer
5. Practical convenience in procuring and handling the fertilizer
6. The sanitary effects that the material may have

Elements in fertilizers

The three elements that are supplied in commercial fertilizers are nitrogen, phosphorus, and potash. When all of these are present the fertilizer is said to be complete, although it does not contain all the plant-food elements. Sulfur may receive more attention in the future as a constituent of fertilizers. When the carrier or material containing the plant-food is of plant or animal origin, the fertilizer is termed organic; when from other sources, it is termed mineral.

A fertilizer may be used to supply any one or two or more plant-food elements. The selection will depend on the farmer's conclusion as to the material required by his soil and his crop.

Table 4 gives the quantities and combination of plant-food in the more common fertilizer materials:

TABLE 4 COMPOSITION OF THE COMMON FERTILIZER MATERIALS

	Availability	Pounds per hundred							
		Nitrogen	Phosphorus		Potash		Calcium		Sulfur
		N	P_2O_5	P	K_2O	K	CaO	Ca	S
Nitrogen carriers									
1. Sodium nitrate	r s	15							
2. Ammonium sulfate	r s	20							22
3. Potassium nitrate	r s	13			44	30.5			
4. Calcium cyanamid (lime nitrogen)	r s	10–16					40	28	
5. Calcium nitrate	r s	12–14					52	22	
6. Cottonseed meal	s s	7.5	2.5	1.0	1.8	1.5			.8
7. Dried blood (red)	r s	14							
8. Dried blood (black)	r s	6–12							
9. Tankage	m s	4–10	2–18	1–8			10–15	7–10	
10. Tankage (concentrated)	m s	10–12	2–4	1–1.8			8–12	5–8	
11. Fish (dried)	m s	8–10	5.5–7	2.5–3			7–8	5–6	
12. Fish (acidulated)	m s	5	3	1.3			4–5	3–4	1
13. Dried meat	m s	13–14							
14. Hoof meal	v s s	10–15	1.5–2	.7–.9					05
15. Garbage tankage (variable)	s s	3–5	1.5–3	04–.6	.7–1.5	.6–1.5			
16. Dried manures	m s	1–2.5	1.5–2	.6–.7	.8–1.5	7–1.2			
17. Nitrogenous guanos	m s	7	9	4					
18. Hair	v s s	14–16							.6
19. Leather meal	v s s	7–12							
20. Wool waste	v s s	5–6	2–4	.9–1.8	1–5	8–2.5			6
Phosphorus carriers									
21. Acid phosphate	r s		15–18	5–8			22–27	15–19	8
22. Basic slag phosphate	r s		10–18	4–8			42–45	29–32	.4
23. Rock phosphate	s s		27–36	11–16			38–50	27–35	
24. Raw bone meal	s s	3–4	21–25	9–11			32	33	
25. Steamed bone meal	m s	2–5	23–25	10–11			54	24	
26. Bone black (animal charcoal)	m s		25–35	11–15			45–50	25–35	
27. Dissolved bone black	m s		15–16	5–7			15–18	11–14	.7
Potassium carriers									
28. Muriate of potash	r s				50–53	41–44			
29. Sulfate of potash	r s				48–51	40–52			16
30. Potash manure salt	r s				11	9			5
31. Potash double manure salt	r s				22–24	26–29			8
32. Kainit	r s				12–13	10–11			12
33. Carnallite	r s				13–14	10–11			3
34. Wood ashes	m s			4.9	4–7	3–6	25–40	17–25	

Key: r s = readily soluble; m s = moderately soluble; s s = slowly soluble; v s s = very slowly soluble

Fertilizer materials may differ widely in the availability of the plant-food contained. For example, nitrogen in nitrate of soda is very much more readily soluble than in cottonseed meal or, especially, in untreated hair and hoof meal. Phosphorus in acid phosphate is readily soluble and in raw phosphate rock it is slowly soluble. No fertilizer material is made up of plant-food alone. The plant-food element occurs in combination with some other material. For example, one form of potassium fertilizer is sulfate of potash (K_2SO_4), a definite chemical substance that contains when pure 38 per cent of potassium, which is equivalent to 46 per cent of potash (K_2O).

Mixed fertilizers

Mixed fertilizers are made by combining different materials containing plant-food, the selection being determined by the composition and availability desired, the soils and crop to be treated, and the cost of the material.

Brands are merely trade names for different combinations of the carriers of plant-food.

Do not buy fertilizer merely because of its trade name.

Knowledge of fertilizer materials, facility of their preparation, mixing, and storing, and experience with their use on different crops and soils, make a legitimate basis for factory-mixed commercial fertilizers.

Inspection of fertilizers

The farmer is protected as to the guaranteed analysis of commercial fertilizers sold in New York by the *fertilizer inspection service*, which licenses all fertilizer material that sells for more than $5 a ton, analyzes samples collected from farmers, and reports such analyses in comparison with the company's guarantee. These data are published as an annual bulletin from the State Agricultural Experiment Station at Geneva, which is distributed to applicants without cost.

The trade price of a fertilizer bears no relation to the benefit which that fertilizer may produce. That depends on the soil and the crop.

It is often practicable for the farmer who understands fertilizer materials to buy the desired materials and mix them to suit his own conditions. There may be a saving in cost and improvement in the result, since the *carriers* are known.

It is first necessary to decide on the approximate composition of the fertilizer to be used and the form or forms in which each element is to be applied. If one were to mix number 1 of the combinations given on page 27 — which is one of the best high-grade general-purpose fertilizers — it should have two carriers of nitrogen, one readily soluble and the other more slowly available for later use. It may carry some slowly available phosphorus. Assuming that one half of the nitrogen is in the form of nitrate and one half in some organic carrier, and that acid phosphate and sulphate of potash are the carriers of phosphorus and potassium, the calculation would be as follows:

Composition of fertilizers, 4 per cent nitrogen, 10 per cent phosphoric acid, 6 per cent potash.

(1) One half of 4 per cent of nitrogen as nitrate equals 2 per cent.
(2) One half of 4 per cent of nitrogen in organic form equals 2 per cent.
(3) Nitrate of soda contains 15 per cent of nitrogen.

(4) Steamed tankage contains about 6 per cent of nitrogen and 12 per cent of phosphoric acid in the form of bone phosphate, both of which are slowly available.
(5) Use sulfate of potash containing 46 per cent of potash.
(6) Use enough 16-per-cent acid phosphate to fill out the ton.

(7) 20 cwt. (in one ton) $\times$ 2 per cent N $=$ 40 lbs. nitrogen $\div$ .15 (nitrogen in nitrate of soda)=	267 lbs. nitrate of soda.
(8) 20 cwt. (in one ton) $\times$ 2 per cent N $=$ 40 lbs. nitrogen $\div$ .06 (nitrogen in tankage) $=$....	667 lbs. tankage.
(9) 20 cwt. (in one ton) $\times$ 6 per cent K_2O $=$ 120 lbs. potash $\div$ .46 (potash in sulfate of potash) $=$..............................	260 lbs. sulfate of potash.

(10) The total weight of these materials is........ 1,194 lbs.
(11) 2000 lbs. (in one ton) —1194 lbs. (nitrogen and potassium carriers) $=$ 806 lbs. (acid phosphate to make one ton without filler).
(12) The proper amounts of nitrogen and potash have been introduced in the materials used. The 806 pounds of 16-per-cent acid phosphate will contain 129 pounds of phosphoric acid. The 667 pounds of tankage carrying 12 per cent of phosphoric acid will add 80 pounds of phosphoric acid.
(13) 129 lbs. + 80 lbs. P_2O_5 $=$ 209 lbs. $\div$ 2000 (lbs. in one ton) $=$ 10.5 per cent of phosphoric acid in the mixture, which is approximately the amount required by the formula. Should the total of the materials used be less than one ton, some filler may be introduced to make up bulk and, if possible, add to the value of the fertilizer. Raw ground phosphate rock is excellent for this purpose. Fertilizers rich in nitrogen and potash in mineral carriers are likely to be lumpy and hard, due to the natural properties of those materials if no filler is used; and a filler that has a drying effect is very beneficial.

In mixing, a screen should be used, and a mill to crush the lumps will be useful.

Put the materials on the mixing floor in the order of their bulk, beginning with the largest. Mix them several times and pass through a screen. If permitted to stand for more than a few days most combinations will become somewhat lumpy.

The Ohio Experiment Station has demonstrated that home-mixed fertilizers will give as good results as factory-mixed fertilizers of the same composition of food elements.

High-grade fertilizers are more economical to buy than low-grade fertilizers. In Vermont, in 1913, the value of plant-food received for one dollar spent for various grades of fertilizers was as follows:

Low-grade fertilizer (1 per cent nitrogen, 8 per cent phosphoric acid, 4 per cent potash)...	55 cents
Medium-grade fertilizer (2 per cent nitrogen, 8 per cent phosphoric acid, 5 per cent potash).........................	61 cents
High-grade fertilizer (4 per cent nitrogen, 8 per cent phosphoric acid, 10 per cent potash).............................	68 cents

The residue of a fertilizer should be considered Some residues are desirable; others may be injurious. When the plant-food is on the acid side of the compound, a basic residue is left. This aids in sweetening the soil. Examples are nitrate of soda and basic slag. In other fertilizers the plant-food is on the basic side of the compound and an acid residue remains. Examples are sulfate of ammonia, muriate of potash, and sulfate of potash. These render the soil more acid and increase the need for lime.

Organic fertilizers have some value for the organic matter supplied in addition to the plant-food.

Quantity and kind of fertilizer used

The quantity of fertilizer used must be related to the value of the crop treated. The higher the acre value of a crop, the larger the quantity of fertilizer that may be used profitably. The season when a crop grows influences the need for fertilizers. Grain and hay crops may usually receive an application of 200 to 400 pounds, potatoes 600 to 1000 pounds, garden and vegetable crops 1000 to 2000 pounds, and fruits 500 to 800 pounds.

Crops that mature seed are usually those most benefited by phosphorus. Crops that make a large vegetative growth in leaves, roots, and flowers, and are used for those parts, are especially benefited by nitrogen. Potassium is most used in the stems and roots; this element gives stiffness to straw, and is especially beneficial to leguminous crops and to root crops.

Plants that start growth in early spring or late fall generally are benefited by the addition of a little available fertilizer, especially nitrogen.

The *most reliable method* of determining the fertilizer need of a soil is a *field test.*

In the absence of knowledge that the soil is well supplied with one or more elements in available form, the safest plan is to use a moderate quantity of a complete high-grade fertilizer. The following are some good standard combinations in percentage:

	Nitrogen	Phosphoric acid	Potash
(1)	4	10	6
(2)	4	8	10
(3)	3	11	5
(4)	2	8	12
(5)	3	5	15
(6)	6	8	4

Numbers 1 and 3 constitute good fertilizers for almost any crop on a normal soil. Numbers 2 and 4 are relatively stronger in potash for potatoes, root crops, and legumes. Number 5 is especially suited for muck soil. Number 6 is especially a vegetable fertilizer on normal upland soil in good condition.

Generally, large applications of fertilizers should be thoroughly mixed with the soil rather than placed in the hill or the row. Small applications

of fertilizer — 500 pounds or less — are usually best applied in the hill or the row for crops planted in that manner.

For more complete information the following books may be consulted:

Fertilizers and Crops. By L. L. Van Slyke. $2.50. Orange Judd Company.

Soil Fertility and Fertilizers. By Jas. E. Halligan. $3.50. Chemical Publishing Company.

Manures and Fertilizers. By H. J. Wheeler. $1.50. The Macmillan Company.

CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Farm Management

SOME SUGGESTIONS FOR CITY PERSONS WHO DESIRE TO FARM

G. F. Warren

This circular is prepared to make a few suggestions to the considerable number of inexperienced persons who are making farm investments. For a number of years large numbers of such persons have been writing to the College of Agriculture for advice. It is not often possible, in the limits of a letter, to fully answer the questions asked, nor will it be possible in a circular, but a few of the more common questions and mistakes may be discussed. The writer is well aware that the facts and opinions here presented are not popular, but he believes that if carefully considered they may save many misfortunes that are sometimes tragedies. It is not the purpose of this circular to persuade any one to farm or not to farm. The aim is to give a better understanding of what may be expected from a farm, and to suggest the safer ways of procedure for those who are starting farming. The facts here presented are based on records of large numbers of farms.

Profits to be expected in farming. Farming is a very conservative business and, like all conservative enterprises, it gives conservative returns. Compared with large city enterprises, farming is a very small business and, like other small enterprises, too much should not be expected from it. It is a very complicated business and requires considerable experience for success. For one who knows how to farm, it offers a wholesome living and a modest profit.

In the best townships in Jefferson county, in a year fully as good as the average, the average farmer and his family with a capital of $9006 made $1155 above the business expenses of the farm. In addition they had the use of a house and some farm products. The houses are nearly all heated by stoves, with wood that comes from the farm. Usually not more than one stove is kept burning besides the one in the kitchen. Probably less than one in a hundred of the farmhouses has a bathroom. The majority of the houses are such as would rent for $10 to $20 a month in a village. In this county the farms usually furnish potatoes and milk and some vegetables, eggs, and meat for family use. The $1155 represents the amount that the average family had for living, aside from what the farm furnished, and for saving. This should not be compared with city wages because the farmer has capital invested. At 5 per cent the use of the capital is worth $450, and unpaid farm work done by members of the family was valued at $96, so that the pay for the farmer's

work, or his labor income, was $609, besides the use of a house and some farm products. This is considerably above the average for the State, but is exceeded in some townships in the State. In 16 townships in three counties of 1988 farmers 63 made labor incomes of over $2000, that is, made 5 per cent interest on the capital and had over $2000 besides the use of a house and some farm products as pay for the year's labor. Farming does not often give what in the city are considered large profits, nor is there so great danger of large losses. Bulletins 295 and 349 of this station give some of the variations in profits made by different farmers.

A common wage in New York for experienced hired men is $30 a month, with house, land for a garden, firewood, and a quart or two of milk a day. In some of the more prosperous parts of the State, $35 is often paid. Very rarely does a hired man get more than $40 by the year. Unmarried men are paid about $5 a month less than married men, but are given their board. Inexperienced men are, of course, worth much less. The above figures may give some idea of the profits in farming.

The glowing stories about farming that are told in many publications have led to very wrong conclusions as to the profits to be expected. A recent article that is typical stated that the farmer made $2400 a year from one enterprise and that he made 120 per cent on the capital. But no allowance was made for labor of men, horses or machinery. Depreciation, taxes, and insurance on buildings were omitted, to say nothing of the multitude of miscellaneous expenses.

To call the difference between the value of the feed and the returns from live-stock profit, is just as inaccurate as it would be to call the difference between the cost of leather and the value of shoes the profit of a shoe factory. This error is very common in farm publications.

Popular publications are of course looking for striking things. Headlines stating that John Jones and his son rose at five o'clock, milked the cows, worked in the fields all day, and milked the cows again at night, and made a dollar and a half apiece by so doing, would probably not add to the circulation any more than would the statement that merchant So-and-so went to the store in the morning, stayed there all day except for a hurried lunch, returned home for supper, and that by so doing he made enough to pay his modest living expenses. Publications are usually not looking for the ordinary, they are looking for the unusual; that is, for the news — and the news is sometimes highly colored.

Compared with city work, farming is a very much better business than many farmers think it to be. It is a much poorer business than many city persons think it to be. At one of the Farmers' Week lectures, the writer gave the results from some of the most successful farms in the State. After the talk, an intelligent farmer stated that he did not believe any farm ever made so much money. An equally intelligent city business man criticized the talk even more severely because it did not show profits enough.

How big a business is a farm? The following statement from a recent letter is typical:

"I want to buy a farm and go to farming scientifically. I have always had a love for outdoor life and find that my present occupation is too confining for my health. I have about $5000 and have thought that you

might possibly know of some good graduate of the College of Agriculture who would act as superintendent for me for a share of the profits. We would prefer a married man so that he could board the help."

Very few farmers who have only $5000 invested in the business employ much if any hired labor. In fact, a farm with this amount of capital is usually a one-man farm. The graduate of a college who would act as superintendent of this farm should be able to do all the work himself, if not interfered with too much by the owner. There would usually be nothing left for the owner to do and no other hired help to board.

A farmer running such a farm would ordinarily make a labor income of about $350. A person who is not so vitally interested would not be likely to run the farm so well. It takes more ability to run such a place and make any profit than it does to run a larger enterprise successfully. A graduate of a college of agriculture who has the experience and the ability that are necessary to make a profit on such a farm is a man who can earn $800 to $1200 a year in any one of several different kinds of work. In short, this represents too small a business to make it pay to hire a graduate.

A few farmers who use this amount of capital are doing well, but they are the exception. A considerable number who know how to farm are doing well when the owned capital is not more than $5000 and when nearly as much more is borrowed. It is not safe for any but experienced farmers to be so heavily in debt. Another way of obtaining more capital is to be a renter. Many renters with less than $5000 of their own are doing well.

Judging by the profits that farmers make, 5 per cent of the capital would be very high pay for a manager. It will be seen at once that no small business would justify one in employing a graduate of an agricultural college as a manager. Usually it requires a wise investment of $20,000 to $40,000 in order to justify one in employing a really good graduate of a college of agriculture who has had good farm experience and good business experience.

A general or dairy farm with this amount of capital will usually employ three to six men. A good manager of such a farm does not conduct his business from an office; he should be at work with the men and should do as much farm work as any other man on the place. No industry can afford a non-working foreman for so few workers.

In sixteen townships in three counties, the 23 most profitable farms selling market milk at wholesale had an average capital of $19,728. Their average area was 257 acres, of which 154 acres were in harvested crops. These farms kept an average of 32 cows, besides young stock. These large profitable farms employed an average of 3.2 men, or a little over two men besides the farmer. With this amount of help, the stock was cared for and, in addition, enough cash crops were raised so that over one third of the income came from the sale of crops. The crops sold for enough to pay the entire feed bill and have left an average of $1553 per farm. For a business of this size, inexperienced persons often employ two or three times as many men.

Farming a slow business. The returns from money invested in farming are very slow compared with most enterprises. Farming is a family business. The returns from some investments do not even come in the farmer's lifetime; they are made for his sons.

Farming is not a factory process. It depends on living things. Many of these things cannot be hurried. If one starts to improve his soil, he will not get far until he has carried out one full rotation. This usually takes six years on the dairy or live-stock farms. At least a second rotation must be carried out before the full returns come in. The successful live-stock breeder takes time. The favorite cow may persist in raising bull calves, so that the herd is not soon replaced by her daughters. An investment in tile drains is a good thing for many farms, but we do not expect them to be paid for at once.

The man who plants an apple orchard has a long-time investment. Orchard surveys of four counties published by this station indicate that the average apple orchard does not yield much until it is over twenty years old. The maximum production is reached at forty to fifty years of age. There are varieties that bear younger, but they also die younger. The old standards, such as the Baldwin, are long-lived trees that have a long youth as well as a long life.

So it is with nearly all the best farm investments. Returns come slowly. Many an amateur at farming starts out with too rosy views, and becomes discouraged at the expense and time before things have had a chance to pay.

Cost of living on farms. Approximately half of the food of farm families is furnished by the farm at a cost much below what it costs in cities. The purchased food usually costs as much as, or more than, it does in cities. City water rent is very much cheaper than the cost of furnishing running water in the house on most farms. Light is cheaper in cities unless the farmer uses kerosene lamps, as they nearly all do. High school education is often very expensive for farm children, because it is often necessary for the children to leave home and pay board, or a horse may have to be kept for the children to drive to school and this is very expensive even on a farm. The fact that food and house are cheaper on the farm makes the farm most attractive for persons with large families and small means, because such persons spend most of their money for food. The children can also be of much help in the farm work. At the same time the children not only receive the benefits that come from wholesome labor, but also learn much about plants and animals. Persons who have an income so large that food is not the chief item in the cost of living are likely to be disappointed in their expectations of a greatly reduced cost of living on farms.

A farm a home enterprise. Farming is very different from most city occupations. The success of a farm is dependent on the entire family. All the members of the farm family take some part in the farm business. The women usually help by taking care of the hens and in some of the other farm work. They go to town to get farm supplies, often board some of the hired help, and usually take a considerable part in other farm operations at times of unusual pressure of farm work. They often direct the farm work during the absence of the head of the family. Children on farms practically always help with the work. There are many things that a small boy can do as well as a man. It is not of vital importance to the family whether one is a carpenter or a mason, but when one decides to be a farmer the family must be consulted, because farming is a family occupation.

One of the primary advantages of a farm is its value as a place to bring up children. The farm provides a healthful and wholesome life. Children on a farm learn to take life and work seriously. They have the best form of apprenticeship by working with their parents. The reason why farm boys get along so well in cities is primarily that they have learned to take an interest in their work and have learned to stick to it even if they had rather not. Children who have grown up in idleness in a city do not often take kindly to the discipline of farm life. The family that can derive much of its pleasure from the labor on the farm has one of the most important qualifications for success in farming. The primary ways of overcoming the isolation of farm life are to derive pleasure from work and to be able to entertain oneself by reading.

The many other advantages of farm life are fully discussed in the magazines. The purpose of this circular is not to discuss the advantages or disadvantages of being a farmer but to give some cautions to those who are going to start farming.

First learn the business. There are several reasons why one may wish to buy a farm. One may desire to live on a farm while he continues his employment in the city. One may want a farm as a country home. Or one may desire a farm as a place on which to make a living — that is, a real farm.

If the farm is to be a home only, it is of course desirable to know something about farming, but it is not necessary because the living is made in some other business. The farm is not expected to furnish the income, but, if the aim is to make farming a business, then one should learn the business before he invests money in it. The farm boy who goes to town starts in at the bottom and serves some time in subordinate positions before he enters business for himself. If a successful farmer should decide that he desired to go into the grocery business, he should begin in a subordinate position in order to learn the business. It would be very unwise for him to start by buying a store before he had had any experience. It is even more unwise for one who has never farmed to buy a farm before he knows anything about the business. The way to gain the necessary experience is to work for a farmer as a hired man. The failure to appreciate the necessity of an apprenticeship before starting farming is the reason why a circular such as this is needed. If prospective farmers were willing to learn something about the business before starting, they would not make the many errors that call for this advice. The almost universal error of the city man is over-confidence in his ability, and lack of appreciation of generations of farm experience.

Selecting a farm. If an amateur hopes to make money by farming, he should go where the present farmers are prosperous. The cheap farms are a great attraction to many. But the inexperienced person is the last one who should buy a poor soil. His lack of knowledge will be handicap enough without the addition of poor soil. When land sells for little, it is because in the experience of the farmers of the region there is little or no profit in farming it. The newcomer who laughs at the present farmers in a poor region and thinks that they could do well if they would only follow his advice is an "easy mark" for the land agent. One may be sure that, if the land is good, some one in the country will have discovered it. Even

in the poorest community, some farmers have plenty of ability. An absolute proof of this ability is the facility with which they can sell a poor farm to an over-confident prospector for several times its value. By all means, the prospective farmer should locate on a good farm in a prosperous community. His chances of success will be much greater, and if he fails as a farmer the capital in the farm can be recovered because such a farm is salable.

It requires the intelligence and skill of the most experienced farmer to make a profit from poor soil. It is just such soil that is ordinarily sold to city persons and to persons from a distance. Good land sells readily to the neighboring farmers. It does not require advertising in order to make it sell. The poor land of the South is often sold to Northerners. The good land is readily salable to persons who know it. The poor land in New York is often sold to men from the West and to men from the cities. The good land does not have to hunt for a buyer.

Land values for many miles from New York are based primarily on the home value rather than the value for farming. The movement for country homes has made much of the land double in price. Such land is sometimes a good speculation as it may rise in price. It is often very desirable for those who wish a country home and who expect to continue in the city occupation. But if one wishes to make a living from the soil, it is much safer to go where the farmers who depend entirely on the farm are making good profits

The farm should have buildings that are sufficient for the purchaser's needs. Good land with buildings can be purchased for little more than new buildings would cost. But the buildings without good soil are useless. The prosperity of the farm depends on the soil. No matter how good the buildings are or how attractive the view is, if the soil is not good the place is certain to prove a disappointment financially. One should not be misled by what can be done on the soil. A given amount of outdoors can be made a good soil if one has the money to spend, but to make it pay is a different problem. A good soil is one that nature made good.

Large crops do not necessarily pay. The beginner nearly always overestimates the importance of large returns per acre. Economy of land is usually much less important than economy of labor and other costs. From cost accounts on a number of New York farms, the following costs per acre were shown:

	Potatoes	Oats	Hay
Rent of land	$4.42	$4.09	$3.78
Cost of man, horse, and equipment labor	42.19	11.15	4.49
Other costs	22.00	6.28	3.44
Total cost	$68.61	$21.52	$11.71

The use of land is about one sixteenth of the cost of growing a potato crop. It is less than a fifth of the cost of the oat crop and a third of the cost of a hay crop. By experience, the practical farmer has learned where to economize. He may not be able to express his views in terms of efficiency engineering, but a very large number of farmers have arrived

at the correct practice. The writer is never favorably impressed by the amateur's large yields per acre unless he knows the cost. The way to make money on potatoes is to have the cost per bushel less than potatoes sell for. Fairly good crops are likely to be a help in reducing the cost of production, but phenomenal crops are likely to cost too much. The amateur is likely to figure how many cows he can keep on an acre by using the soiling system. The experienced farmer is not so much concerned with the cow population as he is with saving the labor cost. Economy in the use of labor of men and horses, and a reduction of the machinery cost, are more important by far than is economy in the use of land. When we arrive at the conditions of high-priced land and cheap labor of Europe, we will give relatively more attention to the saving of areas.

There are some profitable farms that obtain very large receipts per acre; these are usually with types of farming in which the expenditure per acre is also large.

Correct types of farming. One who has traveled much is likely to be impressed by what is done in some other State and may want to try it in New York. He sees hogs eating corn in Iowa, and is likely to think that the New York farmer should raise as many as does the Iowa farmer. He buys an expensive steak, and concludes that beef would pay every New York farmer. Nearly all the pasture land in New York is already in use producing milk or raising dairy cattle. New York farmers have tried practically everything. The types of farming that have survived are the ones that have stood the test.

Over-investment in buildings and machinery. In Livingston county, the investment in houses represents 14 per cent of the total capital in the farm business, including real estate, equipment, live-stock and supplies. Certainly, one should hesitate to build a new home that represents much over a fifth of the capital. The house may be said to be a personal matter, but, if the investment goes much beyond this, it is too valuable a house for the farm.

The average cost of barns per cow or equivalent in other animals was $70 in Livingston county. One who spends over $100 per cow should be sure that he is right. The interest, repairs, taxes, insurance and other costs on such a building amount to about 8 to 10 per cent. The above limit would make an annual cost of $10 per cow for barn rent. One set of barns were built not long ago which were intended to be model barns for the neighbors. They cost $65,000 and were to house 65 cows. The barn rent per cow would be $100 a year. It takes a good cow to give $100 worth of milk at wholesale prices. There are many such examples in this State. Nearly all the so-called model barns are so expensive as to be impossible on a business farm. Hen houses ought not to cost much over $1 per hen. At this cost, the hen must lay a half dozen eggs to pay her house rent. Many of the big poultry farms have such expensive buildings that the plant cannot possibly pay.

The danger of over-investment in machinery is even greater, for there are skilled agents whose business it is to make sales. The average farm in Livingston county has an investment in machinery of $6 per acre of crops. Many a farm of an amateur has ten times this amount. The machinery on a general farm ought not to cost over $10 per acre of crops. The complete cost of maintenance, housing, interest, repairs, and deprecia-

tion on farm machinery amounts to about 25 per cent of the inventory value. A \$10 investment per acre of crops represents a cost of about \$2.50 per acre per year.

Raise crops first. The temptation of the beginner is to spend his first year or two in a complete revision of all buildings on the farm. Such changes nearly always cost twice the estimated amount. Unless one has a large amount of money, he is likely to find that when he gets his buildings ready he has no money left for farming. This mistake is a very natural one to make, because in cities, buildings in themselves are often a business But on a farm the foundation of the business is the crops grown. The way to begin farming is to raise crops. If one cannot make a profit at this, he has no need for buildings. It is better to put off the desire for changes for a few years. One will then know better what he wants. He will also know whether he desires to remain on the farm. Money invested in buildings is rarely returned when one sells.

Learn from the neighbors. The beginner should follow the practice of the best farmers of the region, for the first few years at least. In every community there are farmers who understand farming as well as the most successful railroad president understands railroads. The newcomer with his theories nearly always scorns the experience of the generations of farmers. He fails to realize how old a science agriculture is. The words of Dr. A. D. Hall, formerly Director of the Rothamsted Experiment Station, show the modest point of view to which he arrived as a result of his many years of scientific investigation.

". . . Agriculture is the oldest and most widespread art the world has known, the application of scientific method to it is very much an affair of the day before yesterday. Nor can we see our way to any radical acceleration of the turnover of agricultural operations that shall be economical; the seasons and the vital processes of the living organism are stubborn facts, unshapable as yet by man with all his novel powers."

The newcomer fails to realize that in every prosperous farming community there are farmers with minds as keen as any industry can command. Manufacturing enterprises are so much under control that the city man comes to have great faith that by the aid of science and business he can do what he wills. The farmer who has spent a lifetime trying to control the stubborn forces of nature is less confident of the powers of man and science. He has never seen two seasons exactly alike. His plans are every day subject to revision by the weather. He may be excused if his plans are not always clear-cut.

Many public-spirited men of wealth desire to establish farms where, with the aid of college graduates as managers, they can show farmers the results of the application of scientific and business principles to farming. There are already examples in every county of farms that are demonstrating how best to farm under the circumstances. Furthermore, a demonstration of how to farm with unlimited capital is of little value to the tenant or the small owner whose chief problem is not to know what it would pay to do, but to know what to do with his limited means. The college graduate who wants to demonstrate how to farm can best do it by starting as other farmers start and making his money while he farms.

The newcomer should at first humbly follow the example of the best farmers. Any attempt to be a model for the farmers nearly always results

in amusement for them at the expense of the newcomer. After one has learned how to farm in the region, he may cautiously try new things if he has not by this time learned that they have already been tried and found unprofitable.

Starting as a young man without capital. A young man can take up any kind of business that he likes, and if he first prepares for the business and then works hard at it he may hope for success. The way to prepare for farming is by working as a hired man on a farm. Visiting on farms does not prepare one for farming, any more than visiting in town prepares one to be a banker. There is no way to learn to farm except by farming. It is an excellent thing for city boys to work as farm laborers during the summer vacation while they are in high school.

It pays a young man to make a thorough preparation for any business before he goes into it. Such a preparation for farming includes work at an agricultural college as well as work as a farm hand. Neither one can take the place of the other. The work on a farm should precede the college work. It is a serious mistake for one who plans to farm to take a college course in agriculture before he has worked on a farm. There are many reasons why the farm work should come first. Not until one has worked on a farm does he know whether or not he wants to be a farmer. Many young men are quickly cured of any such desire as soon as they find out what farming means. The sooner such men find this out the better. Others like farming better than they expected to. It is a great mistake for parents, or any one else, to try to make farmers out of young men who are not going to like farming. When a young man is deciding what his life work is to be, he does not need blinders.

A person who has never worked on a farm is not prepared to take a college course in agriculture. He will gain vastly more from such a course after he has had farm experience. The young man from the city should spend at least one full year on a farm before he takes such a course. Two years would be very much better.

Farmers usually hire men after they have seen them. They do not ordinarily hire by correspondence. If one does not know where to get work, he should go to a farming community and start out in the country to look for work. He will usually get a temporary place if he looks as if he would not be afraid of work. At first an inexperienced city boy is rarely worth his board. As he learns how to be of use, and as it becomes safe to trust him with tools or stock, he will be worth a small wage. If one works well he will usually be paid all he is worth by the farmer or by some neighbor who has observed his work. If the desire to farm still persists after a year or two of farm work, at least a short winter course should be taken at an agricultural college. If possible it is very much better to take a regular four-year college course in agriculture.

Farming for middle-aged persons. A decided change in business is always a hazardous undertaking for any but young men. The man who knows nothing about farming and who has a family to support should be very cautious about leaving good wages in a city and going to farming. Such changes have been made with great success, but there have also been many severe disappointments.

One must learn the business before he can expect success in any occupation, and in any business it is rather difficult to make a living for a family

while learning. Farming is manual labor. Very few persons make a success of farming who are not workers as well as managers, and these few persons nearly always come up through the labor experience. If a middle-aged person has never learned to do manual labor, such a change is still more difficult. If the members of such a family are very sure that they desire to go to farming, it is safer, if possible, to rent a small place in the country and continue with the city occupation. Some chickens and a cow can be kept, and a garden raised. The family can do most of this work. The small enterprises can be increased, and, if successful after a few years, it may be safe to leave the city work and go to farming.

Another safe method of procedure for a man with a family and small means is to put his money in a savings bank and hire out as a farm hand for at least a year before any of the money is invested in farming. The amount of wages received will not be very large, but the danger of losing the entire capital through premature investment may be avoided. Until an able-bodied person is able to earn good farm wages for some one else, he is certainly not ready to direct a farm for himself — no more so than is a clerk ready to run a grocery store before he can earn good wages as a clerk in that store.

The farm as a home. There are thousands of persons who live on farms and who continue with their city occupation. Living on a small place enables one to raise milk, vegetables, eggs and fruit for home use and often some for sale. This greatly reduces the cost of living. It gives a chance to provide useful and wholesome work that is such a vital part of the training of children. One of the greatest helps in encouraging this manner of living is the locating of factories in small villages or towns where the workers can get out to the land. Trolley lines have given a great stimulus to this method of living. In the last ten years there has been a great increase in the number of such places. Railroad freight rates and freight accommodations have often been unfavorable for the small town. This has been one of the chief obstacles to a still greater extension of this excellent movement.

Large farms and corporation farming. Large fortunes are usually made either by speculation or by making a little profit from each of a large number of workers. Many large fortunes have been made by buying land when it was cheap and holding it until it became expensive. Other fortunes have been made by dealing in farm land. But straight farming very rarely creates even small fortunes. Only rarely is there a farm business that compares in size with large manufacturing plants. There are many reasons why "bonanza farms" or corporation farms do not often pay.

The factory system is based on high-priced supervision. Most of the workers have only a few things to learn, and they are under close supervision. It is impossible to give close supervision to large farming enterprises because the workers are so scattered. For general farming, 40 to 80 acres of crops can be raised per worker. The number of men that might be gathered under one roof under the supervision of one superintendent would in farming be scattered over half a county.

For nearly all farm operations, it is necessary that each worker be intelligent and that he take an interest in the work. We cannot have a boss watching the man on a mowing machine. If some one has to watch

the driver, he may as well replace the driver and do the work himself. There are a few operations at which gangs of men can be used, but there are very few cases in which a farm can make a continued use of a gang of men. It is very difficult to get men to take the necessary interest in large farms. If wages are high enough to attract men who will take an interest without close supervision, the high wages take all the profit.

A profit of 10 to 20 per cent on the wages of each worker is a good profit in any industry. If the industry employs a very few men, the profits will be small.

The expense of hauling crops and manure usually makes about 600 acres the limit to run from one center. But for general farming this area with half the land in pasture is a business that, measured in workers, corresponds with a grocery store that employs two or three clerks and one or two deliverymen

The prices of farm products are based on production by the farm family working as a unit. The hired help is usually boarded in the family at much less than it costs to hire it boarded. The women wash the milk pails, care for the chickens, go to town on errands. They very frequently take the place of a man at these light operations, and also very frequently help with farm work. In Delaware county, on 210 of the rather large dairy farms, 20 per cent of the milking and caring for cows was done by women and children. On the smaller farms, the proportion of such labor is much more. All this labor is directly interested. When men are hired to run large farms, it is exceedingly difficult to produce farm products at the same cost at which they are produced by the family-farm system.

More conclusive than the reasons for failure are the results. Literally hundreds of successful business men scattered from the Atlantic to the Pacific have tried running large farms with hired managers. Most of these men have demonstrated their ability to make money in cities. The writer has seen many such farms in a number of States, but has not yet seen a case in which a man who made a fortune in a city has ever added to his accumulations by running a large farm with a hired manager. There are many cases in which the live-stock has taken premiums innumerable and the crop yields have been all that could be desired, but the profits have always been book profits. No farm is a success that does not pay all expenses, a reasonable rate of interest, and good wages to the operator, and have enough money to provide for depreciation. Many college graduates have undertaken the management of such farms. Formerly the writer recommended some of them for such places, but so far the writer has never seen an instance when such a farm paid. Yet these same college graduates have by the hundreds demonstrated their ability to make their own farms pay. Part of the difficulty is the erroneous attempt to apply the factory system to farming operations. Part of the difficulty is that the successful business man makes a fad of farming. He has too many theories to try out.

Most of the big farms that are popularly cited as examples of business organization of a farm have a monthly check come out from the city to meet the pay roll. If the writer were free to give the names of some of the well-known places that have been run for years at a loss, many of which have been written up as great successes, the list would contain many surprises for the reader.

Wealthy men who start farming with the idea of showing farmers how to farm often end by finding out some of the obstacles in the way of farming and joining with the farmers to work for their removal. By aiding in cooperation, in marketing, in obtaining railroad accommodations, and in having laws passed that give the farmer equal rights, such men have done much good. Farmers are no more and no less in need of education or uplifting than are merchants, bankers, mechanics, or any other class of our population. But farmers have been relatively too little heard in legislative halls.

A successful business man may derive much pleasure from a country place. But if he hopes to make money by farming with a hired manager, he had best profit by the experience of others. The first few years are full of hope, for then all expenses can be charged to improvements, but there comes a time when the constant deficit is disconcerting.

The writer is well aware of the fact that some large corporations are making money in farming or in enterprises closely associated with farming. He has probably visited as many such farms as has any one. There are some large nurseries and seedhouses and other large enterprises that are doing well. But these have usually grown by the direct management of their owners. Often several generations of the same family have developed the enterprise. Such enterprises have not often been successful when started by wealthy men from the city who depended on hired managers. About the only way in which such inexperienced men have often made successes has been in buying land and holding it for a rise in price.

Even the large farms of the West where the farming is of the simplest kind are rapidly being broken up or rented. In order to manage a large tract of land profitably, it is necessary to have several centers, and the best method of management for the centers is to give the man a share in the returns, that is, rent the farm. The standard system of giving the worker a share in farm returns is to rent him the place for a share of the products.

An even less hopeful kind of farming is the corporation that sells unit orchards or other parcels of land, when the buyer has nothing to do with the enterprise except to move onto the farm sometime in the future when the farm has been made to order and is to be producing a fine revenue. Such schemes profit from selling to city persons only. Farmers rarely make such investments, except when they are the promoters. Those who understand farming know better than to make such investments.

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CORNELL UNIVERSITY

AGRICULTURAL EXPERIMENT STATION OF

THE COLLEGE OF AGRICULTURE

Department of Soil Technology

OUTLINE OF THE RELATION OF THE USE OF LIME TO THE IMPROVEMENT OF THE SOIL

ELMER O. FIPPIN

In the art of agriculture the use of some form of lime for the maintenance of the productiveness of the soil has long had an important place. The earliest records of agricultural practice show that long ago this treatment was common. In Europe extensive areas of land have been made more productive by the use of lime. In America its use has long been common in certain communities near the Atlantic seaboard, and in parts of Pennsylvania in particular large applications of burned lime were formerly made to the soil at regular intervals. Within the last ten years there has been an extensive revival of the use of lime on the soil, but in much smaller and more frequent applications and with a better appreciation of the treatments and conditions that should accompany its use.

DISTRIBUTION OF LIME IN NEW YORK SOILS

A large part of the land in New York State requires application of lime for the best growth of crops, and especially for success with clover, alfalfa, and the root crops. In the hill sections of New York from southern Wyoming, Ontario, and Madison counties southward, and throughout the Hudson Valley region with the exception of a few small areas, lime is greatly needed by the soil for success with clover, although this may not be the only factor for the successful growth of this crop. In those sections the lack of lime is one of the most important limiting factors in larger crop production. In the remaining cultivated sections of the State the use of some lime is generally beneficial. The part of the State where the soil is best supplied with lime is a strip of land extending southward for a distance of ten to twenty miles from a line passing through Utica, Syracuse, Rochester, and Niagara Falls. That is the chief territory in which alfalfa has been most successfully grown. The subsoil is usually well stocked with lime carbonate and in that region deep plowing is especially helpful.

TESTS FOR THE NEED OF LIME

There is no simple method for accurately determining the need of lime. The use of strips of blue litmus in the wet soil and their distinct change to a pink color in a half-hour is one common test that is indicative of

such need Strips of blue and red litmus paper may be placed in the bottom of a drinking glass and covered with white filter paper or blotting paper on which is placed the soil to be tested. The soil is then moistened with clean rain water until the paper becomes damp. This is a more exact test than the direct application of litmus paper to the soil.

Another method of determining the presence of free bases is to put on the soil a drop of muriatic acid diluted four or five times. If there is any perceptible bubbling, or effervescence, this indicates the presence of sufficient lime. Should lime be shown in the subsoil but none in the soil, a moderate application of lime is likely to be beneficial.

The best indication of the need for lime is the type of plant growth that the soil bears. This will be better understood from the discussion that follows. The vigorous growth of lime-loving plants, such as alfalfa, clover, and the scab of potatoes, indicates the presence of sufficient lime; while the absence or weak growth of plants of this kind, and the predominance of such plants as horse sorrel, white daisy, and redtop, indicate a need for lime.

EFFECTS OF LIME

An understanding of the forms in which lime may be used on the soil and the best methods for its application can be gained only after one has acquired some insight into the chemical nature of the soil and the effect lime may have on the causes of fertility.

On acidity of soil

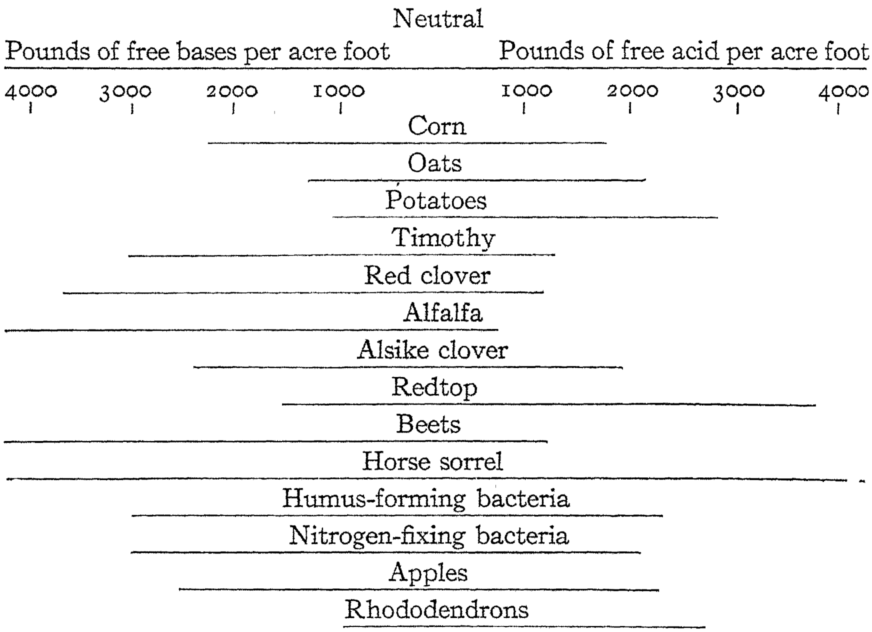
Lime maintains a neutral or an alkalin condition of the soil. The most important effect of lime is to neutralize free acid in the soil and thereby produce a more favorable medium for the growth of plants. The soil is a complex chemical mass made up of two groups of elements and compounds. One group has basic properties, which are sometimes called sweet or alkalin. The other group has acid properties, which are commonly described as sour.

Elements of basic group	*Elements of acid group*
Sodium (Na)	Carbonic acid (CO_2)
Potassium (K)	Muriatic acid (Cl)
Magnesium (Mg)	Sulfuric acid (SO_3)
Calcium (Ca)	Silicic acid (SiO_2)
Iron (Fe)	Phosphoric acid (P_2O_5)
Aluminum (Al)	Nitric acid (NO_3)
Ammonia (NH_3)	Numerous organic acids

The alkalin and acid constituents unite to form neutral (balanced) or nearly neutral compounds that make up the minerals of which the soil is composed. Examples of such union are sodium and muriatic acid to form common table salt, and lime and carbonic acid to form limestone.

The composition of the normal soil is near the neutral condition. Some soils have a greater or less excess of alkalin constituents and are termed alkalin. Others may have an excess of the acid constituents and are termed acid, especially if those acids are appreciably soluble. One important acid constituent of all soils, silica (SiO_2), is so very insoluble that it is not effective to produce a markedly active acid condition of the soil.

Most plants are adapted by long habit to grow in soil that is approximately neutral. A few plants are accustomed to grow in soil having a considerable excess of free acids. Other plants have become accustomed to grow in soil having a considerable free base. These relations of a few common plants are shown in the following diagram, in which the central line represents a neutral, or balanced, chemical condition of the soil:



Many of those crops and microscopic organisms that live in the soil and aid in the maintenance of productiveness, grow best in a soil that is approximately neutral. Some of these prefer a medium that is definitely alkalin; such, for example, are the alfalfa plant and the bacteria that cause nitrification. Few valuable agricultural plants can thrive in a strongly acid soil solution.

Reasons for soil acidity.— As a result of cropping and of weathering and leaching, the basic elements are removed from the soil more rapidly than are the acid elements. The large predominance of silica in the form of quartz sand in old soils, such as those of southern Long Island and the Atlantic coastal plain, illustrates the results of this process. Some fertilizers leave an acid residue in the soil. An example is muriate of potash. The potassium is used by plants as food and the chlorin remains in the soil to form muriatic acid. Any material applied to the soil the basic portion of which is used by plants will build up an acid condition of the soil if its use is continued in sufficient quantities.

As a result of all these processes, every soil tends to gradually accumulate an excess of acid constituents. The greater the original stock of basic material from which the soil was formed, the longer the time

required in order to develop a seriously acid condition. Other soils with a small stock of basic material may become so acid in one or two generations of cropping that plants which are sensitive to acid cannot thrive. This is one reason why clover fails in many sections of the country where it formerly grew luxuriantly.

Basic elements are carried off much more rapidly by the removal of crops than if the crop goes back on the soil. The ash elements of plants generally have an excess of the basic elements. If the crop is left on the soil the alkalinity is nearly or quite maintained, although the subsoil may grow more acid as a result of the withdrawal of the basic elements from the subsoil by the roots and their deposit at the surface when the plant decays. When the crop is removed the accumulation of materials at the surface is not so rapid.

The maintenance of a large quantity of humus in the soil, and the practice of intensive methods of tillage without the addition of basic materials, hastens the rate at which the soil accumulates acid.

Common method of neutralizing soil acidity.— The loss of basic material from the soil must be compensated by the addition of some basic material in sufficient quantity to keep the soil neutral or slightly alkalin. The material most commonly used for this purpose is some form of lime, which is made up of the bases calcium and magnesium. The natural forms of these suitable for use on the soil are limestone, marl, and mussel shells.

On beneficial organisms

Lime favors beneficial organisms in the soil. It has a relation to the microscopic plants in the soil similar to its relation to higher plants. In general it favors those that are beneficial and its presence hinders the growth of many organisms that are injurious.

The organisms concerned with the decay of organic matter into humous material and those concerned with the changes of nitrogen, including the tubercle bacteria on the roots of legumes, are in the former group.

On disease-producing organisms

Lime has an important relation to disease-producing organisms. Some of these are favored by lime. One of the commonest is the organism causing scab on potato. The growth of other disease-producing organisms is prevented by an excess of lime. The commonest of these is the club root of cabbage and other cruciferous plants.

On the availability of plant-food elements

Lime increases the availability of certain plant-food elements. The presence of lime increases the availability of potassium and phosphorus in the soil, and through its influence on processes of decay it increases the availability of nitrogen. Lime may take the place of potassium in minerals containing that element, thereby setting potassium free to form compounds more available to plants. Recent investigations on the effect of lime on the solubility of potassium in the soil have given negative results; but in field experiments applications of lime have frequently had an effect similar to that of applications of potash fertilizers.

The effect of lime on the availability of phosphorus is especially marked

in soils rich in iron and aluminum, with which phosphorus forms very insoluble compounds. Lime phosphate, on the other hand, is measurably soluble in carbonated soil water.

On tilth

Lime improves the tilth of the soil. It improves the tilth of clay soil by causing a more granular condition, as a result of which its drainage and ventilation is much improved.

As a plant-food

The elements of lime — calcium and magnesium — are plant-food. The grain and fruit crops use these as food in very small quantities, but the legumes and root crops use them in relatively large quantities. (See Circular No. 23 of this station, "Outline of the Function and Use of Commercial Fertilizers.")

FORMS OF LIME

Pulverized lime carbonate is the material in the soil most generally found to produce the neutral and alkalin reaction. While many other basic compounds are present, they do not have the value of lime carbonate for this purpose.

Lime carbonate in the form of limestone, marl, chalk, and shells of mussels is widely distributed in nature, often forming thick strata of rock. It is therefore cheap and convenient. Often these rock materials have been worked into the soil in considerable quantities by natural processes. Sometimes this has resulted from the slow decay of limestone to form soil. In other cases limestone has been introduced in the mixing of rock materials incident to the formation of soil by glacial processes. So important is the effect of a generous supply of lime carbonate that the saying "A lime-rich soil is a fertile soil" has become common.

Any form of lime in the soil must be finely pulverized in order to be effective. The solubility of lime carbonate of a sandy or pebbly texture is very low. In order to be quickly active it should be in a flour-like condition.

The use of finely pulverized limestone, marl, chalk, and shells on the soil is good practice. Not only does it have a good effect on the soil, but also it is convenient to handle. Wherever it can be put on the soil at a reasonable price as compared with other forms of lime, its use is generally recommended. On heavy clay and on muck soil caustic lime is usually preferred.

Another form in which lime may be used on the soil is the lump lime or quicklime that results after the limestone is burned. This material is widely used in making plaster mortar; its price has become stable, and for available lime it may be lower in price than the various forms of pulverized lime carbonate.

Caustic lime must also be in a finely pulverized form in order to be effective in the soil. This is accomplished by grinding or by slaking with water.

Lime carbonate consists of calcium oxid or calcium and magnesium oxid united with carbonic acid. When the material is heated to a sufficiently high temperature, the carbonic acid is driven off as a gas, which process does not reduce the value of the remaining material as a source of lime. In fact, it increases its strength pound for pound. The lump lime resulting from the burning may be pulverized to a sufficiently fine granular

condition by passing it through a mill. The commoner method of pulverizing lump lime depends on the fact that when it comes in contact with water there is a vigorous chemical union, which develops much heat and causes the lime to swell in bulk and to change to a very fine powder, called water-slaked, or hydrated, lime. This material also has caustic properties.

Some objection has been raised to the use of any form of caustic lime on the soil, in the belief that it will destroy humus. It is well known that caustic lime is an active destructive agent to organic material when applied in ten-per-cent or larger proportions. Such destructive action in the soil when lime is used at the rate of not more than one or two tons per acre-foot of soil has not been demonstrated. The reason seems to be that the soil water and the soil atmosphere are heavily charged with carbonic acid gas, and when the pulverized caustic lime comes in contact with this a union results to re-form lime carbonate and destroy all caustic properties of the lime. From what is known of the chemical action of these materials, it is evident that such change must be complete in a few days or weeks and after that time the action is the same as if it had been applied in the carbonate form. The change is the same as the air-slaking of lime and the setting of plaster.

Whether to use pulverized lime carbonate or some form of caustic lime on the soil is a practical question depending on relative cost for available basic materials. This depends on their strength, original cost, fineness, freight and handling charges, and convenience of handling and storing.

TIME AND METHOD OF APPLICATION

Lime may be applied at any season of the year when its use is convenient. It should be as thoroughly mixed with the soil as possible. Fall application on the furrow, followed by one cultivation with a disk or spring-tooth harrow, is often the best method. On fallow land it may be applied before plowing, and the result will be somewhat improved if the land can be disked and the furrows set at an angle of thirty to forty degrees.

The ideal method on very acid soil is to apply two thirds of the lime before plowing and one third on the furrow. On soils known to have a fair quantity of lime in the subsoil, application after plowing is preferred.

Lime is best applied just ahead of a tilled crop, such as corn. It may precede oats or wheat, and the added tillage is beneficial. Surface application on grassland will give some benefit, but not so much as where the lime can be more thoroughly incorporated with the soil.

Application may be made by hand with a shovel. This is usually tedious and unpleasant work. Where the use of some form of lime is an established practice, a lime distributor will be a useful implement. There are several kinds of these in the market.

The fertilizer attachment of a grain drill will sow the heavier and more granular forms of lime. It is usually necessary to go over the land two or three times in order to get on the full application. The effect of lime may not be apparent in the first year if the crop grown is not especially sensitive to an acid soil.

Caustic forms of lime should not be mixed with manure, or with a fertilizer containing ammonia or soluble phosphoric acid.

EQUIVALENT STRENGTH OF DIFFERENT FORMS OF LIME

The following is a list of the common forms of lime that may be used on the soil, with notation of their relative strength and points to be observed in handling them. They are compared on the basis of the amount of calcium oxid available in a ton of material. In the first column the comparison is based on the assumption that the material is chemically pure, and in the second column on the average purity of the commercial materials. By effective availability is meant their solubility in the soil within a period of five or six years.

TABLE 1. COMMON FORMS OF LIME AND THEIR EQUIVALENT STRENGTH

Material	Effective lime (CaO) in 2000 pounds of pure material	Effective lime (CaO) in 2000 pounds of average commercial material
1. *Limestone*		
When 100 per cent will pass a 100-mesh screen......	1,120	950
When 75 per cent will pass a 25-mesh screen......	840	715
Limestone may be either pure calcium, or calcium and magnesium carbonate. Magnesium is assigned approximately the same value as calcium to neutralize acid. For New York soils that are already richer in magnesium than in calcium, a lime carrying more than ten or fifteen per cent of magnesium oxid is not considered especially desirable.		
2. *Marl*		
A soft lime carbonate found in swamps ($CaCO_3$). Widely variable in composition. Pure deposit, comparable with limestone of the same fineness.		
3. *Shells*		
From oysters and other mussels. Very pure lime carbonate ($CaCO_3$). Comparable with pure limestone of the same fineness.		

	Effective lime (CaO) in 2000 pounds of pure material	Effective lime (CaO) in 2000 pounds of average commercial material
4. *Lump lime*		
Perfect slaking......	2,000	1,700
Average farm slaking (estimated)......	1,600	1,360

TABLE 1 (*continued*)

Lump lime should be slaked before application. Approximately sixty gallons of water per ton of commercial lime is required. Home slaking may be performed in various ways. The lime may be placed in the field in small piles of a half-bushel at intervals sufficient to give the desired application. These will usually slake in a week or ten days, and should then be immediately distributed while in a powdered form. Another method is to place the lime in large piles and add water at intervals as the pile is built up. The result will be improved if the pile is covered with moist soil. A third, and still better, method is to mix the lump lime with wet soil and let it stand for a few days so that complete slaking will occur. The passage of the material into a pasty condition is to be avoided. Lump lime is inconvenient to handle and to store.

	Effective lime (CaO) in 2000 pounds of pure material	Effective lime (CaO) in 2000 pounds of average commercial material
5. *Hydrated lime*		
Fresh water-slaked lime	1,314	1,400
Six months old (estimated)	1,300	1,200

Hydrated lime [$Ca(OH)_2$] is derived by factory-slaking lump lime. It is convenient and safe to store.

Lump and hydrated lime are caustic, and therefore unpleasant to handle. They should be kept off man and horses as much as possible.

USE OF LIME

Frequent small applications of lime are better than occasional large applications. One thousand to fifteen hundred pounds of active lime per acre once in five or six years will generally put a soil in good condition, and one half to two thirds of this quantity thereafter should keep it in condition. Sufficient lime of any form should be used to give this quantity of effective lime.

Clay soil needs larger applications of lime than does sandy soil.

Wet soil needs larger applications of lime than does well-drained soil.

Soils rich in organic matter need more lime than do those low in organic matter.

Very sandy soils may well receive a third less than the quantity mentioned.

Legumes and root crops that use much lime and prefer an alkalin soil may well receive an application fifty per cent greater. Where convenient, the annual application of three hundred to six hundred pounds of lime per acre, especially after a larger initial application, is good practice.

The following materials commonly used as fertilizers also contain lime in the quantities indicated. In the first two materials, the lime is already

united with strong acid and has no ability to neutralize acid in the soil. The last five materials tend to render the soil alkalin because of the bases that they contain.

TABLE 2. FERTILIZER MATERIALS THAT CONTAIN LIME

Material	Chemical form	Effective lime in 2000 pounds of average commercial material
Land plaster (gypsum)	$CaSO_4$	440
Acid phosphate	$CaH_4(PO_4)_2+CaSO_4$	450
Raw rock phosphate (floats)	$Ca_3(PO_4)$	1,000
Basic slag phosphate (Thomas phosphate powder)	$(CaO)_4P_2O_5$	850
Wood ashes	$CaO+CaCO_3$	500
Lime nitrogen	$CaCN_2+CaO$	1,150
Lime nitrate	$Ca(NO_3)_2$	1,000

LIST OF MANUFACTURERS OF LIME DISTRIBUTORS

American Seeding-Machine Company, Springfield, Ohio.
Belcher and Taylor A. T. Company, Box 200, Chicopee Falls, Massachusetts.
Empire Drill Company, Shortsville, New York.
Hench and Dramgold, York, Pennsylvania.
Ontario Drill Company, Deposit, New York.
Spangler Manufacturing Company, York, Pennsylvania.
Greenwood Manufacturing Company, Lawrence, Massachusetts.

PUBLICATIONS ON THE USE OF LIME ON THE SOIL

Fertilizers and Crops. By L. L. Van Slyke. Chapter XX.
Manures and Fertilizers. By H. J. Wheeler. Chapters XIX to XXII.
The Agricultural Utilization of Acid Lands by Means of Acid-tolerant Crops. United States Department of Agriculture, Bulletin No. 6.

Annual reports, Pennsylvania State College:
The Agricultural Use of Lime, pages 15 to 154. 1899–1900.
General Fertilizer Experiments, pages 68–93. 1907–1908.
(See also Annual Reports of Rhode Island.)

Bulletins, State Agricultural Experiment Stations:
Ohio (Wooster). Plans and Summary Tables, pages 114–115. Circular 120.
Rhode Island (Kingston). Influence of Lime on Plant Growth. Bulletin No. 96.
Tennessee (Knoxville). Liming for Tennessee Soils. Bulletin No. 97.
Virginia (Blacksburg). Lime for Virginia Soils. Bulletin No. 187.
Maryland (Agricultural College). Lime, Sources and Relation to Agriculture. Bulletin No. 60.

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PEACH CANKERS AND THEIR TREATMENT[1]

R. A. JEHLE

(*Received for publication July 28, 1914*)

Cankers are prevalent on all varieties of peach trees and are found on wood of all ages, from the trunk of the tree and the larger limbs to the growth of the current year. They are always more or less injurious to the tree, either killing the branches on which they occur or weakening them so that the set of fruit is decreased. The extent of the injury depends on the number and size of the cankers. Cankers are prevalent on peaches throughout the State, but are particularly abundant in the older peach-growing sections (Plate I). Two very distinct types of cankers occur—brown rot cankers, and cankers caused by injuries of winter, the latter commonly designated as frost cankers; other types are often found, but not in such abundance.

BROWN ROT CANKERS

As indicated by the name, the brown rot canker is caused by the same fungus (*Sclerotinia fructigena*) that produces the brown rotting of the fruit. Blossoms are also attacked and blighted (Plate II, B), but peach-growers are not generally cognizant of the amount of injury that comes from such infection. Whether it is the blossom or the fruit that is attacked, there is always the probability that the fungus will pass into the fruit spur, and thence frequently into the twig or the limb (Plate II). Affected twigs usually are girdled, and the leaves beyond the point of entrance wilt and turn brown. The fungus often passes down affected twigs into the larger limbs.

When a limb is reached, the fungus spreads in all directions. Soon a sinking of the tissue is noticeable and this is followed by the formation of a gum pocket. Later the diseased bark cracks and splits and the gum oozes out in a sticky mass (Plate II, C). The fungus grows up and down the branch more rapidly than around it, and the diseased area is thus longer than broad. The blighted twig or spur remains in the center of the dead area and often persists there for several years. Even when it is broken off, the fact that it was there can be determined easily by cutting in with a knife.

The fungus grows noticeably faster during periods when the tree is in an actively growing condition. Just as the tree responds to increased moisture from rainfall, so the fungus responds to increased moisture in the sappier tissue of the tree.

During the intervening periods of dry weather, when the fungus is less active, the tissues of the tree begin a healing process at the margin of the diseased area, throwing up a roll of tissue known as a callus. Sometimes the fungus remains quiescent or dies and the wound is healed over. Usually, however, the callus eventually is invaded. This process may be

[1] A report of work performed on the industrial fellowship established by the Newfane Fruit Growers' Association, through whose financial cooperation the work has been made possible.

epeated from year to year, the canker increasing in size each time. The approximate age of the canker can be determined from the number of rolls. Ordinarily one roll represents a year, although two rolls may form in one year.

The annual formation of a callus about the diseased area makes the limb broader at that place, and the failure to form wood over the cankered area flattens it (Plate III). The old bark gradually breaks away, and black molds growing over the masses of dried gum make the canker black and rough. Larvæ of the peach-borer are often found in the gum and add to the roughness.

FROST CANKERS

Frost cankers are oftenest found on the main trunk of the tree, usually near the surface of the ground or at the snow line of the previous winter (Plate IV); in the crotches of the larger branches (Plate V); or about pruned stubs (Plate VI). They appear after a hard winter, particularly one of extreme changes in temperature and more particularly when such a winter follows a very late growing season. The cankers appear in the spring as slight depressions. These are made more apparent as the tree puts on new growth of wood over the area not affected. Gum pockets usually form under the flattened areas and the gum often oozes out during periods of wet weather. The injured area is usually rather indefinite about the margin, and the formation of a healthy roll of callus is thereby much retarded. Fermentation of the dead tissue occurs and various fungi and insects quickly follow. One fungus, *Valsa leucostoma*, comes in so commonly that sometimes it has been regarded as the cause of the trouble.[2]

OTHER CANKERS

Both the cankers described above are characterized by an exudation of gum. Almost any injury to a peach tree made during an actively growing period will initiate a gummy degeneration, or gum canker. Thus injuries made by careless use of tools, by hail, or by careless pruning, may develop into gummy cankerous areas. Such injuries are likely to heal over, but when the affected area is invaded by various fungi or insects a gum canker usually results.

CONTROL

It is obviously much better to prevent the formation of cankers in the trees than to treat them after they appear. Also, their recurrence in treated trees should be prevented if possible.

Prevention of brown rot cankers

Control of blossom blight

The control of blossom blight is an important factor in the prevention of canker formation. It may be accomplished by destroying the sources of spring infection. In New York orchards this means disposal of mummies, both those on the ground and those clinging to the trees; those on the ground, however, seem to be the more important sources. These may be destroyed by early spring plowing. Obviously the plowing must be done shortly before the blossoming period. In many orchards this is usually possible, but in many others it is not.

The same result may be accomplished by destroying the rots and the soft

[2] *Valsa leucostoma* isolated from frost cankers on peach trees has been used repeatedly for inoculating healthy trees, but only with negative results.

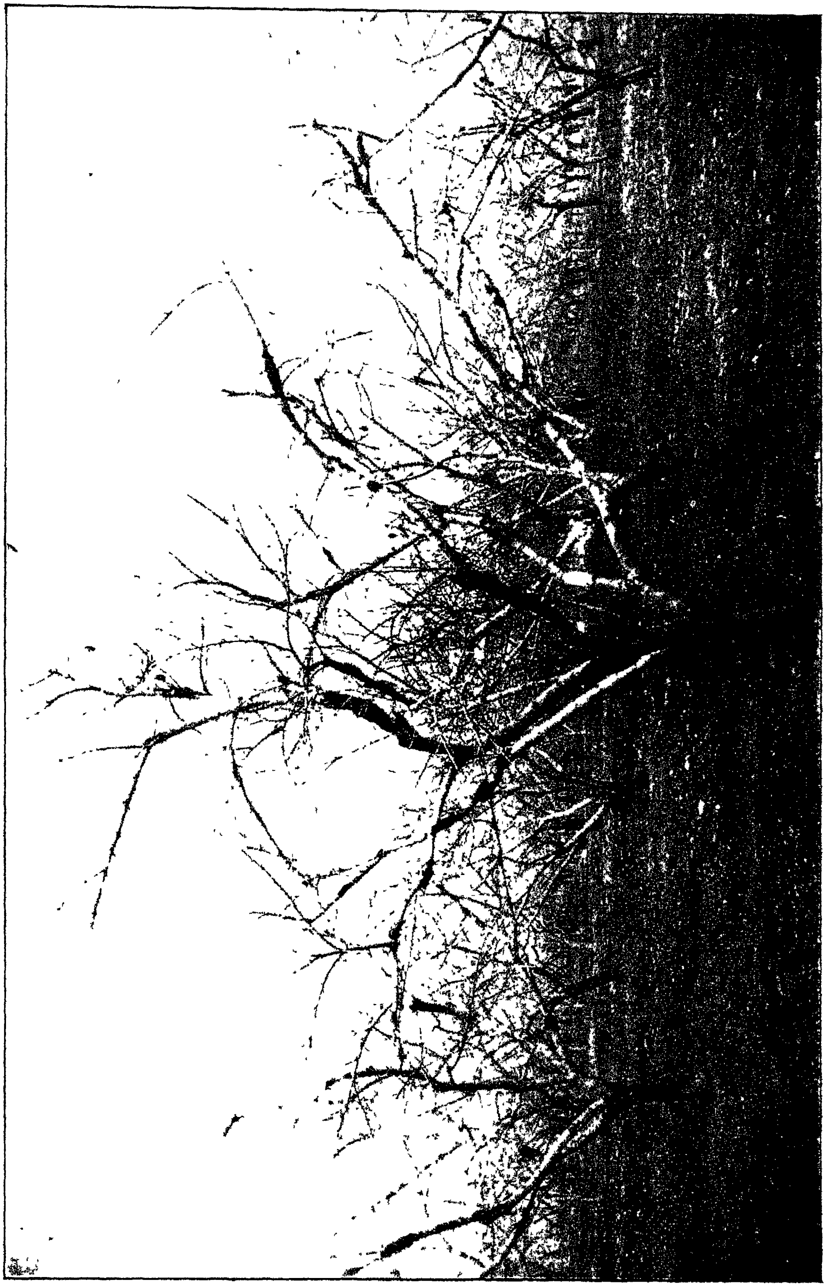

PLATE I.— PEACH ORCHARD SEVERELY INFECTED WITH BROWN ROT CANKER
Photograph made April 27, 1911

PLATE II.— YOUNG CANKERS AND THEIR ORIGIN

A, *Girdling and blighting of twig by way of a rotted fruit. Gum is oozing at the base of the canker. Natural size. Photograph made October 15, 1913*

B, *Blossom blight. The blossoms are held in place by a mass of gum, and cankers are beginning to appear*

C, *Young canker in a large limb. The spur through which the fungus entered is broken off. Gum flow is copious. Natural size. Photograph made June 28, 1914*

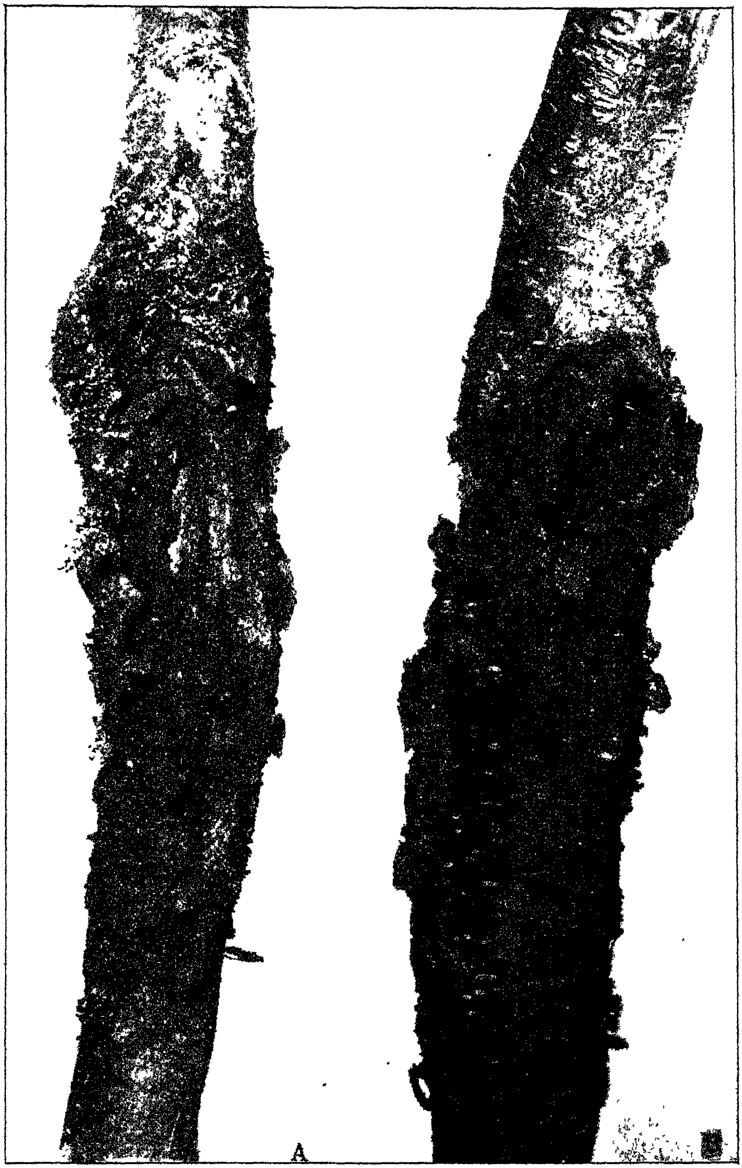

PLATE III.— BROWN ROT CANKERS

A, The twig through which the fungus entered the limb shows clearly at the center. The rolls of wood, the dried remains of gum, and the rough and blackened appearance, are characteristic

B, A canker viewed from the rear. The limb is practically girdled

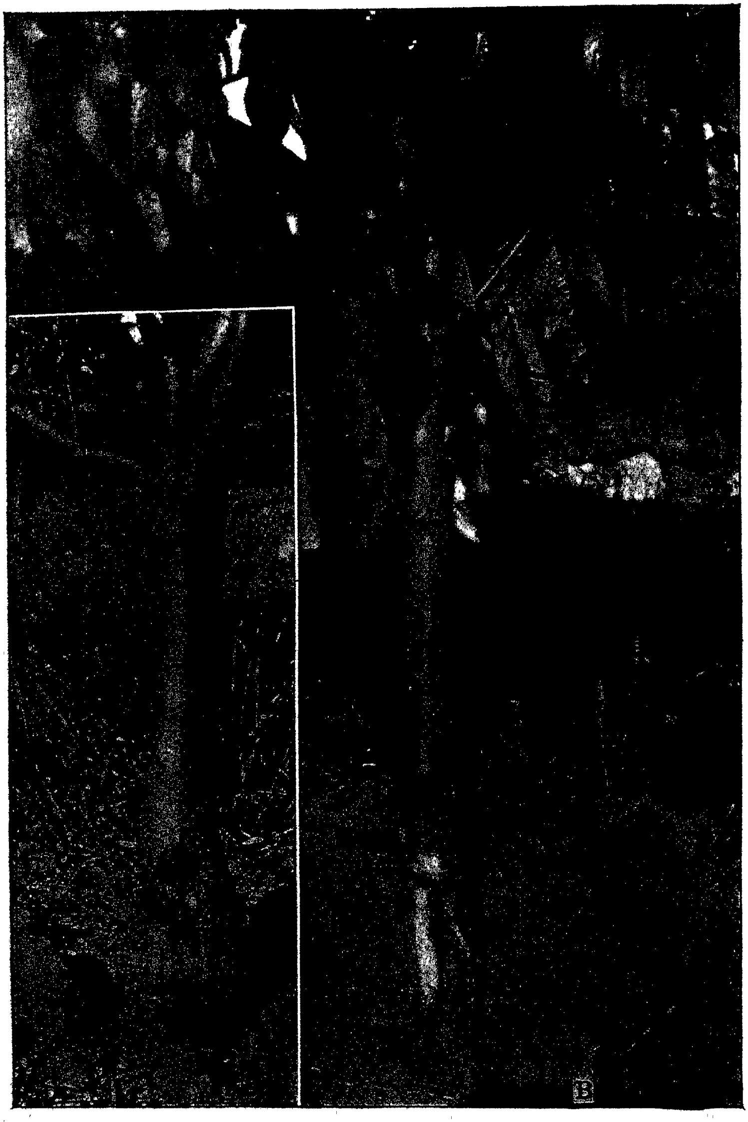

PLATE IV.— FROST CANKERS

A, Frost canker at snow line. Photograph made September 20, 1911, by F. M. Blodgett

B, Frost canker on younger tree than is shown in A. The dead tissue was removed on June 20, 1911, leaving less than two inches of healthy bark. Note particularly the large roll of healthy tissue. Photograph made September 20, 1911, by F. M. Blodgett

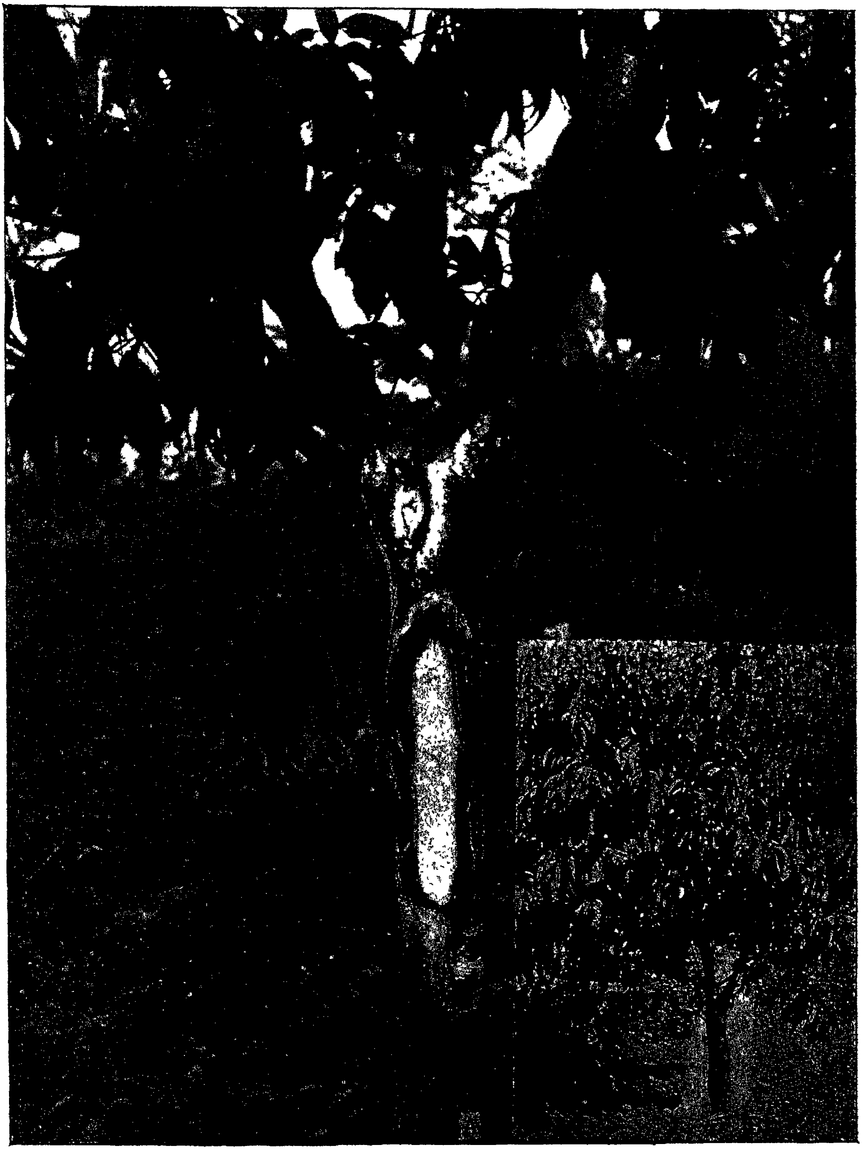

PLATE V.—FROST CANKERS

A, Trunk and crotch cankers removed on June 20, 1911. Photograph made September 20, 1911, by F. M. Blodgett. Note the large roll of healthy callus

B, Frost cankers in this tree were also treated on June 20, 1911, but the photograph was made on August 25, 1913, by J. L. Weimer. Note that the wounds have nearly healed

PLATE VI.—FROST CANKER ABOUT PRUNED STUB

Such stubs should be avoided by making the cut parallel to the main limb. Photograph made June 28, 1914

PLATE VII.— TREATMENT OF BROWN ROT CANKERS

Photographs made in July, 1911. All somewhat reduced, and no two to exactly the same scale

A, Canker before treatment. Note exuding gum
B, Diseased tissue removed and wound ready for preservative
C, Exposed area treated with gas tar

PLATE VIII.—TREATED CANKERS

A, *A small canker treated in August, 1911. Somewhat enlarged. Photograph made June 28, 1914*

B, *A large canker treated in August, 1911. Somewhat reduced. Photograph made June 28, 1914. Note the large roll of healthy callus*

peaches at harvest time. All such fruits should be dropped to the ground, where they may be raked up and drawn off or where hogs, if given an opportunity, will soon make an end of them.

Some method of spraying the expanding or recently opened blossoms might prove effective, but experimentation along this line is too meager to more than suggest the trial of commercial lime-sulfur solution diluted at the rate of one part to forty or fifty parts of water.

Control of fruit rot

Likewise the control of fruit rot is involved in canker prevention. This may be accomplished by the use of Scott's lime-sulfur mixture.[3]

In New York orchards the application of this spray mixture a month before picking time seems to be most important, although one or two earlier applications are sometimes advisable.

Even when spraying is practiced, a certain amount of brown rot may occur. This is likely to come on late, on overripe fruits left hanging to the trees, and especially on such fruits as have been left because of injury by wasps or other insects. Disposition of such fruit has been discussed under the preceding heading.

Protection of large limbs

When blossoms or fruits occur on short spurs issuing directly from the large limbs, the possibility of destructive canker formation resulting is greatly increased.

In case of infection the fungus must grow only an inch or two through the spur in order to reach the limb and begin the formation of a canker in a limb in which is involved a third, a fourth, or a fifth of the bearing area of the tree, as the case may be. Such spurs should be rubbed off at pruning time.

Fertilization

It has been observed that brown rot canker is more abundant in well-cultivated orchards that have been highly, not to say excessively, fertilized with nitrogenous fertilizers. Some growers, however, are aware of this fact and still insist on the use of fertilizer (stable manure) as the best means of securing satisfactory crops of fruit. This would seem to be a matter that each individual must work out for himself.

Prevention of frost cankers

It is impossible to predict the character of the winters, but one can judge by the growth and maturation of the wood what the probabilities are that a tree is in good condition to withstand a severe winter. Soft, poorly matured wood is easily injured. The use of highly nitrogenous fertilizers, particularly their use too late in the season, is to be avoided. In seasons of drought followed by abundant autumn rains a second growth is not uncommon. This may be prevented or held to a suitable minimum by the use of cover crops.

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[3] This is not a boiled solution, as might be inferred from the name. It is prepared by placing in a barrel eight pounds of best stone lime, to which is added a small quantity of cold water in order to start it slaking. Eight pounds of sulfur worked through a sieve to break up the lumps is then added to the slaking lime, which is kept from burning by the addition of just enough cold water so as not to drown it. The slaking mixture must be stirred constantly. Just as soon as the slaking is completed (which should be in five to fifteen minutes), fill the barrel with cold water (fifty gallons). The mixture is strained into the sprayer tank through a sieve of twenty meshes to the inch. It must be agitated constantly while being applied, as it settles rapidly. When properly made this is merely a fine mechanical mixture of lime and sulfur produced by the heat and bubbling action of slaking, and should have but little sulfur in solution. This mixture is especially adapted for the spraying of peaches and plums in foliage, as it causes no injury. Arsenate of lead may be added to the mixture.

Treatment of cankers

Whatever the origin of cankers, their treatment is essentially the same except that in the case of an infectious disease, such as the brown rot canker, the work must be done with great care in order to insure that all trace of the fungus is eliminated.

Whenever the cankers occur on limbs that can be removed without detriment to the tree, it is best to remove them while pruning; care being taken to cut several inches below any visible injury, as the living fungus in the brown rot canker extends back beyond any external evidence of the disease, and if allowed to remain will continue to infect healthy wood. If the cankers occur on limbs that it is desirable to save, they should be cleaned out by removing all the diseased wood a short distance back of any visible evidence of the disease. The diseased wood and bark can be readily detected by its brown color. In the brown rot cankers it is very important to remove all this discolored tissue, as it is in this tissue that the fungus lives and if it is not removed the disease will spread. The amount of bark that it is necessary to remove depends on the extent of the diseased part. Sometimes the fungus has extended so far beyond the healthy callus that it is necessary to remove it entirely (Plate VII A); while at other times the fungus may have extended but slightly into the upper and lower extremities of the callus and it is necessary only to remove a small part. It is always well to leave as much of the callus as possible, to facilitate healing. All the dead bark and twigs should be removed. It is not necessary to remove any of the solid wood except to smooth the treated part. The wound should be pointed at the upper and lower extremities and the bark should be cut at right angles to the wood (Plate VII, B). As soon as the wound has dried out it should be coated with gas tar [4] (Plate VII, C). The gas tar acts as a disinfectant and preservative, and no other treatment is necessary. Trials have been made in order to determine this point, and it is now evident that the use of corrosive sublimate or lime-sulfur solution in addition to the gas tar is unnecessary. Numerous brown rot cankers were variously treated in August, 1911. In June, 1914, the small cankers that had been treated were entirely healed (Plate VIII, A), and the larger ones had formed several inches of callus (Plate VIII, B).

Frost cankers treated on June 20, 1911, by Messrs. Blodgett, Wallace, and Reddick in Orleans county, healed very rapidly as may be seen from the accompanying photographs (Plates IV and V), some of which were made three months later. In the case of the tree shown in Fig. B of Plate IV, only a very small amount of healthy bark was left, yet at the end of three months a remarkable roll of new tissue had developed and the tree showed no ill effects whatever so far as could be judged by the appearance of the foliage.

The tools needed for such work are in the possession of every fruit-grower. A good, stout pruning knife, a pruning saw, a gouge, and a mallet comprise the list.

The time required to treat cankers varies greatly with their size and condition. Small cankers readily accessible can be treated quickly with the pruning knife, while crotch cankers involving several limbs may require an hour. A man can average fifty cankers in a day of eight hours. Labor is the largest item of expense, as a gallon of gas tar, costing 20 to 40 cents, will cover approximately 400 cankers.

[4] This is residue in the manufacture of illuminating gas from coal, and can be obtained at any gas works.

INDEX

F

S

W

Y

Z